
Award of the 700 MHz and 3.6-3.8 GHz spectrum bands

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N.B In some places in this document we draw on commercially sensitive evidence supplied to us in confidence. This evidence is redacted in the published version of this document. Where we have redacted passages of text or illustrations it is indicated by [REDACTED].

1. Overview

We manage the airwaves – or spectrum – used by all wireless devices, including mobile phones. Reliable mobile services have become essential to how people live and work across the UK, and mobile phone networks must keep pace with the growing needs for capacity and for coverage. This is a priority for us. We want to see coverage of good quality mobile broadband from a choice of providers, wherever people live, work and travel.

In this document, we set out proposals for an award of spectrum to enable the industry to provide services with greater capacity and wider coverage, and to pave the way for companies to take advantage of new wireless technologies, including 5G – the next generation of mobile technology. Importantly, we are proposing to provide strong incentives for the companies which participate in the award to invest in providing better quality services in rural areas, furthering our ambition to achieve comprehensive mobile coverage for people right across the UK.

In brief

We propose:

- an auction to award national licences for spectrum in the 700 MHz and 3.6-3.8 GHz bands;
- discounts on auction prices for any two bidders committing to substantial coverage obligations, aimed at providing good quality mobile services in rural areas throughout the UK that currently have patchy coverage;
- to use a combinatorial clock auction format, which would allow bidders to bid on packages they compose from spectrum lots in the two bands, with or without coverage obligations;
- a cap of 416 MHz (37% of the total) on the cumulative spectrum for mobile services held by any winner in the auction;
- potential options to facilitate rearrangement of fragmented holdings of spectrum in the 3.4-3.8 GHz band – although our current view is that this is likely to be best achieved by trading between operators.

We aim to have concluded the auction by Spring 2020.

This overview is a simplified high-level summary only. The proposals we are consulting on and our reasoning are set out in the full document.

The spectrum we are awarding

- 1.1 We are preparing to award **200 MHz** of spectrum: 80 MHz in the 700 MHz band and 120 MHz in the 3.6-3.8 GHz band. One of our statutory functions is managing the radio spectrum – the airwaves used by wireless devices like mobile phones. This involves allocating spectrum and ensuring it is used for the benefit of UK citizens and consumers.

- 1.2 Both the bands we are proposing to award are likely to be used by phone networks to meet the increasing demand for mobile broadband services, and to invest in deploying technical advances, including 5G, the next generation of mobile technologies. Specifically:
- The **700 MHz** band is well suited for providing mobile coverage over wide areas and indoors. We are currently clearing this band of transmissions for Digital Terrestrial Television (DTT) and by wireless microphones used in the entertainment industry for programme-making and special events. Spectrum in this band can be used to improve the level of mobile coverage across the UK, including mobile voice and data coverage in rural areas, and in buildings and other harder-to-reach places. This band should become available for mobile use by **May/June 2020**.
 - The **3.6-3.8 GHz** band is also particularly suitable for the provision of mobile services. It is part of the 3.4-3.8 GHz band, which has already been harmonised for mobile services and identified as the primary band for 5G services in Europe. The spectrum we are making available in the 3.6-3.8 GHz band would allow network operators to support high data rates and provide high capacity to large numbers of connected devices. We are clearing this band of its current fixed links and satellite uses. This band should become available for mobile use by **June 2020**, but some localised constraints may remain in place until the end of 2022.

Our objectives

- 1.3 Our policy objectives for this award derive from our statutory duties, which we have applied to the specific circumstances of the frequency bands we are proposing to award. Our main objectives are:
- improving mobile coverage;
 - ensuring efficient allocation of spectrum;
 - sustaining strong competition in mobile markets; and
 - ensuring the timely availability of spectrum.

Our proposals

Coverage obligations

- 1.4 Our ambition is to achieve comprehensive mobile coverage for people right across the UK. We are working towards this ambition with governments and with the industry. We are concerned that the geographic availability of mobile services, particularly good quality data services, is not currently good enough in many areas across the UK.
- 1.5 We think this award presents an important opportunity for us to take a substantial step to improve good quality coverage for people where they live, work and travel in rural areas across the UK. This will increase the number of places in which consumers can reliably

make and receive mobile phone calls, and use mobile data services such as web browsing and streaming video.

1.6 In March 2018, we published for consultation our initial proposals for including coverage obligations in this award. Having reviewed responses to that consultation, we have revised those proposals. In summary, we are now proposing to include two coverage obligations in the award, each requiring the obligated operator, within four years of the grant of licences in the award, to:

- a) provide a good quality mobile service outdoors in at least 90% of the UK landmass, including at least 90% of England, 90% of Northern Ireland, 74% of Scotland and 83% of Wales;
- b) provide good quality service outdoors for at least 140,000 premises to which it currently does not provide good coverage; and
- c) deploy at least 500 new wide area mobile sites.

1.7 We propose that mutually agreed roaming arrangements onto a host network should be allowed to count towards fulfilment of these coverage obligations - provided the service onto which the obligated operator roams meets the obligation requirements.

1.8 The minimum coverage requirements we propose for each UK Nation are designed to ensure the greatest increase in coverage for those nations with the least coverage today.

1.9 In developing these revised proposals we have considered the potential costs and benefits alongside implications for our other objectives for the award. Although we believe our proposals can provide benefits to many people, especially those living and working in rural areas with poorer mobile coverage, this award does not provide an opportunity to address all coverage issues that people experience today. We will continue to work with the mobile industry and the UK and Devolved Governments on complementary initiatives to achieve better mobile coverage.

An auction of national licences for spectrum in two bands

1.10 We propose to hold a single auction to award licences for 700 MHz and for 3.6-3.8 GHz spectrum, to enable winning bidders to bring the spectrum into use as soon as possible, so that people and businesses can benefit quickly from improved services.

1.11 We have considered whether we should award the spectrum in the form of local, regional or national licences. We have provisionally concluded that awarding national licences would be most likely to achieve optimal use of the spectrum. This is primarily because both the 700 MHz and the 3.6–3.8 GHz bands are particularly suitable for the provision of mobile broadband services, for which there is nationwide demand.

1.12 We want to encourage the development of innovative new uses which will benefit both businesses and consumers. We have published a document alongside this consultation setting out our proposals for future sharing of frequencies in the 1800 MHz, 2300 MHz and 3.8–4.2 GHz shared spectrum bands, and for means by which alternative users could seek

access to any awarded mobile spectrum in locations where we agree that this won't impact upon the incumbent licensee.¹

Auction design

- 1.13 We propose to use a form of combinatorial clock auction (CCA) to award the spectrum. This would allow bidders to choose to bid on packages made up of spectrum in different bands, and coverage obligations.
- 1.14 We are proposing to offer the two coverage obligations as 'coverage lots' alongside and separate from spectrum lots in the auction. Each coverage lot would carry an associated discount, up to a maximum set by Ofcom, on the price of spectrum. We propose a maximum discount in the range £300m-£400m for each obligation. We believe that this should provide a strong incentive for bidders to bid for a coverage obligation alongside spectrum (potentially including either or both 700 MHz and 3.6-3.8 GHz spectrum), although there would be no obligation on bidders to bid for the obligations.

Competition assessment

- 1.15 We have considered the state of competition in the provision of mobile services, and whether there are any competition concerns which should be addressed in the design of this award.
- 1.16 We believe the UK market is generally operating well with continuing innovation and relatively low prices compared to other markets internationally. We consider nevertheless that certain extreme outcomes of the award could give rise to concerns about the strength of competition for mobile services in the UK. In particular, we would be concerned if the auction resulted in very asymmetric shares of spectrum amongst the mobile operators.
- 1.17 We therefore propose to impose a cap of 37% on the proportion of spectrum designated for mobile services which a single mobile operator may hold as a result of the award. This cap would be consistent with the policy we adopted in our 2018 spectrum auction.
- 1.18 In practice, the cap would allow an operator to hold up to 416 MHz after the award. This would limit the spectrum which some operators could acquire in the award, and would mean, for example, that BT/EE, the operator with the largest current spectrum holdings, would not be allowed to win more than 120 MHz of spectrum in this award.

Defragmentation of the 3.4-3.8 GHz band

- 1.19 The 3.4-3.8 GHz band is the primary band for 5G services in Europe. We awarded the lower part of this wider band, the 3.4-3.6 GHz spectrum, in April 2018 and all four UK mobile network operators won blocks of this spectrum. The upper 120 MHz of the 3.6-3.8 GHz band will be included in the proposed award and some of those operators might win additional blocks of this spectrum.

¹ <https://www.ofcom.org.uk/consultations-and-statements/category-1/enabling-opportunities-for-innovation>

- 1.20 We have considered whether we should use this auction to help rearrange (“defragment”) any resulting spectrum holdings dispersed across the entire 3.4-3.8 GHz band, noting that there is a general consensus that a minimum of 80 MHz of contiguous spectrum is desirable for 5G services.
- 1.21 Our provisional view is that the most effective approach is likely to be to allow the market to determine the best allocation of spectrum - both through auction of the 700 MHz and 3.6-3.8 GHz spectrum and through trading of spectrum between licensees. Using the auction to facilitate defragmentation could require the scope of the assignment stage to be widened to include all or most of the currently licensed spectrum across the 3.4-3.8 GHz band. We consider that incentives to participate in such a widened (‘grand’) assignment stage are unlikely to be strong enough to ensure that defragmentation happens, and our power to mandate participation in a grand assignment stage is limited.
- 1.22 We have set out potential options to facilitate post-auction trades through the auction design, including allowing bidders to agree their assignments on a commercial basis, as a possible alternative to conducting a grand assignment stage in the auction.

Coexistence and technical standards

- 1.23 We have considered the coexistence issues that may arise between new services in the 700 MHz and 3.6-3.8 GHz frequency bands and current or existing services, both in those bands and in neighbouring bands.
- 1.24 We propose to require the winning bidders for 700 MHz spectrum to make every reasonable effort to assist the small minority of TV viewers who may be affected by interference from 700 MHz networks.
- 1.25 In the 3.6-3.8 GHz band, we propose to apply technical conditions to maintain current spectrum quality levels for other existing users in the band during the notice period ahead of the revocation of licences for fixed links, and before we stop taking account of registered satellite earth stations for frequency management purposes. We propose to align the technical conditions for the 3.6-3.8 GHz band with those in place for the 3.4-3.6 GHz band, awarded in April 2018. We will supplement these to add extra flexibility to facilitate the deployment of 5G active antenna systems as appropriate.

Next steps

- 1.26 We invite responses to this consultation by 12 March 2019, so that we can take these into account before reaching a final decision. At present, we are aiming to conduct the auction by **Spring 2020**.
- 1.27 Early next year, we plan to give formal notice of our proposals to make a number of statutory instruments in connection with the auction, and consult on them. We will also set out for stakeholders the criteria and methodology that we propose to impose for assessing compliance with the proposed coverage obligations, including the coverage model that we intend to use.

2. Ofcom's policy for this award

- 2.1 We have put together our policy proposals for this award in light of our statutory duties and functions, which come from Parliament. Our principal duty is to further the interests of citizens and consumers, as part of which we must ensure that a wide range of electronic communications services is available across the UK and that optimal use is made of the radio spectrum.²
- 2.2 One of our main statutory functions is managing the radio spectrum – the airwaves used by wireless devices like mobile phones. This involves allocating spectrum and ensuring it is used for the benefit of UK citizens and consumers.
- 2.3 Services using spectrum only benefit consumers if they are actually available in areas where consumers want to use them. We are concerned that the geographic availability of mobile services, particularly good quality data services, is not currently good enough across the UK.
- 2.4 One of the spectrum bands we are awarding (700 MHz) is particularly well suited for improving mobile coverage in rural areas, and we have cleared it with this purpose in mind. We believe that improved mobile coverage is likely to generate significant benefits for citizens and consumers, and as such it forms an important part of our policy for this award.

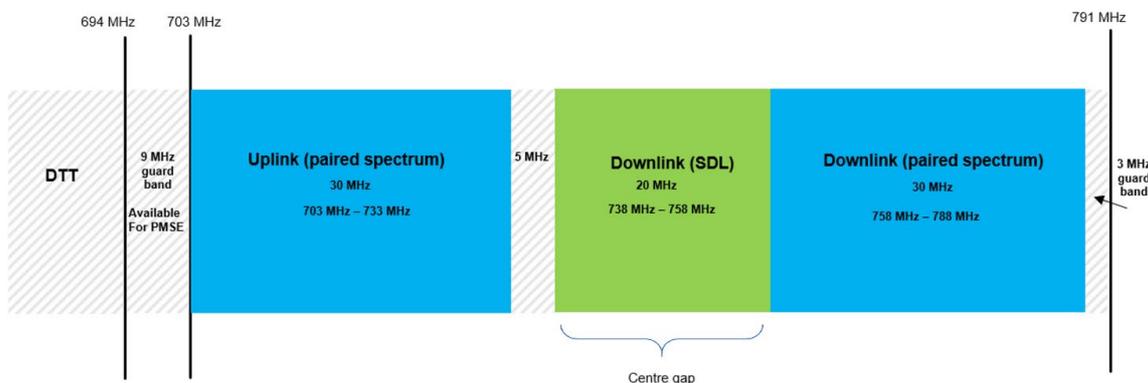
The spectrum to be awarded

- 2.5 We will be awarding 200 MHz of spectrum in total: 80 MHz within the 700 MHz band and 120 MHz within the 3.6-3.8 GHz band.
- 2.6 In summary, the **700 MHz band** consists of low frequency spectrum which by virtue of its propagation characteristics is particularly well suited for providing wide-area and indoor mobile coverage, because signals carried in the 700 MHz band are able to travel long distances and penetrate obstacles such as buildings. As we set out below, in making decisions to clear this band to make it available for mobile use, we have on a number of occasions set out our policy intention to use the opportunities these frequencies offer to improve the level of mobile coverage across the UK, in the interests of citizens and consumers.
- 2.7 The **3.6-3.8 GHz band** is also particularly suitable for the provision of mobile services. It has already been harmonised for mobile and identified as part of the primary band for introducing 5G services in Europe. The large bandwidth available in the 3.6-3.8 GHz band can support higher data rates and provide increased capacity to support large numbers of connected devices, and enable higher speeds to concurrently connected devices.

² Section 3(2)(a) and (b) of the 2003 Act.

The 700 MHz band

Figure 3.1 – The 80 MHz within the 700 MHz band



- 2.8 We will be awarding 80 MHz of spectrum in the 700 MHz band within the 694-790 MHz frequency range. As shown in Figure 3.1 above, this spectrum consists of two x 30 MHz blocks of paired spectrum (703-733 MHz and 758-788 MHz), and a 'centre gap' of 20 MHz at 738-758 MHz. The paired spectrum in the 700 MHz band is configured under a mobile band plan based on a Frequency Division Duplex (FDD) arrangement, with the uplink delivered in the 703-733 MHz frequencies and the downlink in the 758-788 MHz frequencies.
- 2.9 The centre gap is suitable for delivering supplemental downlink (SDL) signals for mobile services³. Alongside the centre gap spectrum we are awarding, there is a 5 MHz guard band at 733-738 MHz, which will not be part of the award.⁴
- 2.10 The 700 MHz spectrum is suitable for early deployment because the chipsets in current mobile devices already cover this band for 4G mobile services. In the longer term, low frequency spectrum such as the 700 MHz band could be suitable for 5G. It may be used to extend the reach of offerings by Mobile Network Operators (MNOs), and deliver a potential uplift in service quality.

Evolution of the 700 MHz band

- 2.11 Until recently, the 700 MHz band has been used on a primary basis throughout Europe for delivery of Digital Terrestrial Television (DTT) services. Other services have shared the 700 MHz frequencies in areas where parts of the band have been left unused by DTT, including

³ SDL spectrum can be used in conjunction with existing mobile spectrum to provide additional downlink capacity .

⁴ Within the broader 694-791 MHz range, there are the following guard bands, which we are not awarding: (a) a 9 MHz guard band at 694-703 MHz to avoid interference between mobile and DTT services; (b) a 5 MHz guard band at 733-738 MHz to avoid interference between the FDD uplink and the SDL in the centre gap; and (c) a 3 MHz guard band at 788-791 MHz to avoid potential interference between the FDD downlink and mobile services in the neighbouring 800 MHz band. There is no need for a guard band between the FDD downlink and the centre gap SDL because the signals operate in parallel and do not risk interference with each other.

Programme Making and Special Events (PMSE) – in particular, radio microphones used in the entertainment industry.

- 2.12 In November 2014 we decided to make the 700 MHz band available for mobile data use.⁵ In our decision document, we explained that consumer demand for mobile data was growing rapidly and we expected that to continue for the foreseeable future.
- 2.13 In considering the benefits of clearing the 700 MHz band for mobile data use, we set out our view that the release of the band could enable improvements in mobile coverage which could go even further than would already be achieved through the coverage obligation we had imposed on the 800 MHz spectrum, which we had auctioned in 2013.
- 2.14 We noted that extending data coverage, possibly through the use of a coverage obligation, could deliver significant additional social and economic benefits, including the benefits associated with the social inclusion of citizens. In our preceding consultation, we set out our view that the net benefits of increases in coverage, whilst difficult to quantify robustly, could potentially be very significant. We note that no consultation respondents disagreed with this assessment.
- 2.15 In July 2015, we published a discussion document setting out the main elements of a wide reaching strategic review of digital communications (the ‘Digital Communications Review’ or ‘DCR’).⁶ We explained that an important part of that review would be to consider how to deliver widespread availability and higher quality of broadband services, including mobile data services, in light of our duty to secure the wide availability of electronic communications services.
- 2.16 We considered various factors which operators take into account when deciding whether and how to invest in mobile networks, including mobile coverage. We noted that whilst competition can provide incentives to invest, it is unlikely to be sufficient to provide universal availability of communications services - and so targeted public policy interventions may be needed to deliver services to the hardest-to-reach areas.
- 2.17 We considered that imposing obligations on specific providers, for example through conditions in spectrum licences (taking into account costs associated with such obligations through lower spectrum receipts) could be one option to extend mobile coverage availability. In this context we highlighted that future auctions could include additional coverage obligations, notably the release of 700 MHz spectrum, given its propagation characteristics.

⁵ Our decisions in this matter are set out in our statement of 19 November 2014 statement (https://www.ofcom.org.uk/__data/assets/pdf_file/0024/46923/700-mhz-statement.pdf), our statement of 17 October 2016 (<https://www.ofcom.org.uk/consultations-and-statements/category-1/maximising-benefits-700mhz-clearance>) and our statement of 14 December 2017 (<https://www.ofcom.org.uk/consultations-and-statements/category-3/coexistence-of-new-services-in-the-700-mhz-band-with-digital-terrestrial-television>).

⁶ https://www.ofcom.org.uk/__data/assets/pdf_file/0021/63444/digital-comms-review.pdf

- 2.18 In November 2015, the International Telecommunication Union (ITU) identified the 700 MHz band between 694 and 790 MHz for mobile use throughout Region 1, which includes Europe.⁷
- 2.19 In February 2016, we published the initial conclusions of the DCR.⁸ Our key conclusion in relation to the availability of services was that whilst the availability of mobile services is good from a UK-wide perspective, some areas do not have access to an acceptable level of service. We said that we would secure the wide availability of services by, amongst other things, exploring options for extending mobile coverage by seeking to place new coverage obligations on companies who win new spectrum licences. We again noted that the 700 MHz band is particularly well suited to providing such coverage.
- 2.20 Following publication of our DCR conclusions, we carried out analysis which suggested that the benefits to citizens and consumers of clearing the 700 MHz band would be greater if it was available sooner than the end of 2021, which was the timetable to which we had at that point been seeking to clear the band.
- 2.21 As a result, in October 2016, we decided to accelerate the clearance of the 700 MHz band by 18 months so as to be in a position to release it in Q2 2020.⁹ We also decided to allocate the ‘centre gap’ (i.e. 20 MHz of spectrum situated in the middle of the 700 MHz band) for mobile data use, specifically for mobile downlink, whilst safeguarding ongoing delivery of DTT and PMSE services.
- 2.22 At present, Arqiva operates DTT multiplexes issued on a temporary basis using the centre gap spectrum. In October 2016, we said that Arqiva could be allowed to operate these multiplexes until at least 1 May 2020, if mobile operators had not rolled out services that were using the spectrum. We have since given notice to Arqiva of revocation of its temporary licences with effect from 21 June 2020.
- 2.23 However, as discussed in more detail in sections 8 and 10, we propose, in certain circumstances, to allow Arqiva to continue using the centre gap to transmit some services on an interim basis after 21 June 2020. We will do this by issuing a new short-term DTT licence, or licences, until the winners of the auction are ready to deploy new services. Were this to happen, we do not envisage the arrangement lasting beyond 30 June 2022 (at the maximum) in any event, in line with the relevant EU Decision.

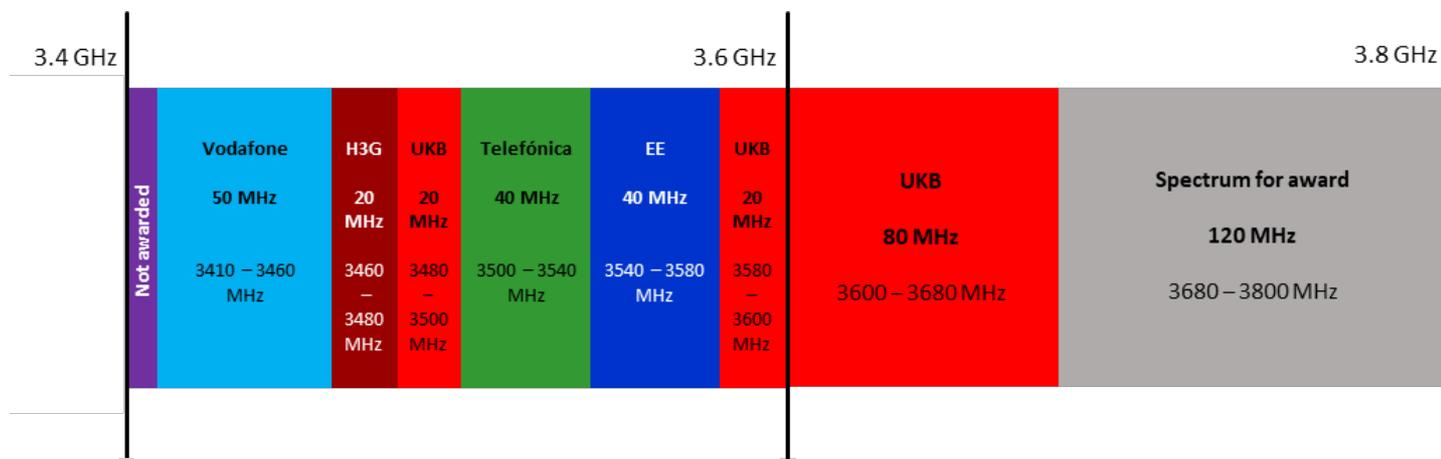
⁷ The ITU took this decision in its 2015 World Radiocommunication Conference (WRC15).

⁸ https://www.ofcom.org.uk/data/assets/pdf_file/0016/50416/dcr-statement.pdf

⁹ https://www.ofcom.org.uk/data/assets/pdf_file/0031/92659/Maximising-the-benefits-of-700-MHz-clearance-Statement.pdf

The 3.6-3.8 GHz band

Figure 3.2: The 3.6-3.8 GHz award band, alongside the already awarded 3.4 GHz band



- 2.24 We will be awarding 120 MHz of contiguous spectrum in the 3.6-3.8 GHz band between 3680 and 3800 MHz. As shown in Figure 3.2 above (which also covers the frequencies in the 3410-3480 MHz band that we awarded in April 2018), the 3.6-3.8 GHz band sits immediately above the spectrum holdings of UK Broadband, a wholly owned subsidiary of H3G.
- 2.25 On 14 December 2018, we granted a licence variation requested by UK Broadband.¹⁰ As a result of this variation, UK Broadband will hold a block of 80 MHz starting from 3600 MHz (3600-3680 MHz) at the time of the auction, instead of a block of 84 MHz starting from 3605 MHz (3605-3689 MHz).¹¹
- 2.26 The characteristics of the 3.6-3.8 GHz band make it particularly suitable for mobile services. As already noted, it has already been harmonised for mobile and identified as part of the primary band for introducing 5G in Europe by the Radio Spectrum Policy Group (RSPG). The first wave of commercial products is expected to be available in 2019-2020. However, initial pre-commercial trials have already begun.
- 2.27 The large bandwidths that one or more bidders might acquire in the 3.6-3.8 band could support higher data rates and provide increased capacity to support large numbers of connected devices, and enable higher speeds to concurrently connected devices.
- 2.28 This spectrum could support mobile services across wide areas, as it could be deployed using macrocells over existing grids. This means it could be used for providing additional capacity for existing MNO networks, in addition to new deployments and uses.

¹⁰ <https://www.ofcom.org.uk/consultations-and-statements/category-2/variation-uk-broadbands-spectrum-access-licence-3.6-ghz>

¹¹ Currently, UK Broadband is also authorised to use an additional block of 4 MHz (3685-3689 MHz) for a transitional period which will come to an end on 14 September 2019. UK Broadband's licence also authorises it to use a further non-adjacent block of 84 MHz outside the 3.6-3.8 GHz band at 3925-4009 MHz.

Evolution of the 3.6-3.8 GHz band

- 2.29 At present, frequencies in the 3.6-3.8 GHz band are used for fixed links, fixed satellite services (to receive space-to-Earth transmissions), and wireless solutions (provided by UK Broadband).
- 2.30 In October 2017, we published a statement¹² confirming that, in order to facilitate deploying future mobile services in the band across the UK, we would vary existing Permanent Earth Station (PES) licences and grants of Recognised Spectrum Access (RSA) such that we would no longer take satellite earth stations with a receiver component in the band into account for frequency management purposes from 1 June 2020. We also said we would revoke fixed links licences with a notice period of five years, but aiming for fixed links operations to migrate out of the band by June 2020 where possible.
- 2.31 In February 2018, we published an update¹³ setting out the decisions we had taken on individual licences and grants. We issued notices to revoke all fixed links licences, effective on 23 December 2022. We varied 12 PES licences and grants of RSA with an effective date of 1 June 2020, and one grant of RSA with an effective date of 1 September 2020.
- 2.32 The effect of these decisions is that spectrum will be available to enable future mobile services in the 3.6 GHz to 3.8 GHz band to be deployed in many areas from June 2020, but not necessarily nationwide before the end of 2022. We also noted that we would aim for fixed links operations to migrate to alternative frequencies or technologies by June 2020 where possible.
- 2.33 Given the notice periods for the revocation of fixed link licences and variation of PES licences and grants of RSA, there may be some constraints on new use of this spectrum in some areas of high population, such as the south-east of England and parts of the Midlands in the intervening period following the award. However, we note that the spectrum is not being used for fixed links and/or satellite services in large parts of the UK.
- 2.34 As a result, there are many areas of the UK, such as most of the north of England, southern Scotland, Northern Ireland and Wales, where future use by licensees would only be expected to be negligibly affected by maintaining existing authorisations, if at all. Spectrum could be useable in those areas immediately after an award. Coexistence issues for the 3.6-3.8 GHz band are discussed in more details in section 9 of this document.

A combined award of the 700 MHz and 3.6-3.8 GHz bands

- 2.35 At any given time, the amount of spectrum available to UK users is limited. We therefore consider it important to make any new spectrum released to the market available for use as soon as practical, even if sometimes the spectrum is not immediately useable.

¹² https://www.ofcom.org.uk/data/assets/pdf_file/0019/107371/Consumer-access-3.6-3.8-GHz.pdf

¹³ https://www.ofcom.org.uk/data/assets/pdf_file/0018/110718/3.6GHz-3.8GHz-update-timing-spectrum-availability.pdf

- 2.36 For this reason, we believe rights to use the 700 MHz and 3.6-3.8 GHz spectrum should be awarded in as timely a manner as possible. This is best achieved by awarding both bands together in a single auction process.

Our policy approach to this award

- 2.37 Our policy approach to this award derives from and is guided by our statutory duties, which we have applied to the specific circumstances of the frequency bands which we are making available. We have set out our relevant statutory duties in greater detail in section 3 below.

Securing optimal use of spectrum

- 2.38 Our main duty in relation to our spectrum management functions is to secure optimal use of the spectrum. Radio frequencies are a major asset to the UK economy and society because they are the means by which all wireless communications devices operate. They are also in scarce supply.
- 2.39 As recognised in the Common Regulatory Framework (CRF)¹⁴, services provided using spectrum can play an important part in relation to social and territorial cohesion, particularly by enabling connectivity in more rural areas. This will be amplified in a new Code to replace the CRF, which places a particular emphasis on achieving widespread connectivity and access to electronic communications services.
- 2.40 We consider that, in general, the optimal use of spectrum is most likely to be secured for society if spectrum is used efficiently, that is if it delivers the maximum benefits (or value) for society. The total value to society from spectrum use derives from two broad sources of value, namely, private value and wider social value.
- 2.41 The private value of spectrum use is the value (for the consumer and service provider) generated as a direct result of the use that is made of it. The wider social value of spectrum use is the value (for others) that is generated indirectly, or as a by-product of the use that is made of it.¹⁵
- 2.42 Our general approach to awarding spectrum in circumstances where demand is likely to be greater than the amount of spectrum available is to allow the market to determine the best allocation.
- 2.43 In most circumstances, we believe an auction is the most appropriate way of allowing the market to determine the most efficient allocation. However, we consider that the particular characteristics of the spectrum available in this award mean that it has the potential to deliver significant wider social value through improved mobile coverage. In

The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC).

¹⁵ See paragraphs 4.6 and 4.7 of Ofcom's statement of 30 April 2014 entitled "Spectrum management strategy", available at: https://www.ofcom.org.uk/_data/assets/pdf_file/0021/71436/statement.pdf

light of this, and for the reasons set out below, we consider that including coverage obligations in the award will ensure it delivers the maximum benefits (or value) for society, and help to secure optimal use of the spectrum.

Improving mobile coverage

- 2.44 Improving mobile coverage for consumers is a key policy priority for Ofcom. Our ambition is comprehensive mobile coverage for people right across the UK.
- 2.45 The geographic availability of mobile services, particularly good quality data services, is not currently good enough in many areas across the UK. We want to use this award to improve coverage for people where they live, work and travel in rural areas across the UK. We are proposing coverage obligations aimed at bringing good quality mobile services to at least 90% of the UK landmass.
- 2.46 As we said in our DCR Statement, coverage obligations are central to Ofcom’s approach to extending the reach of mobile services.¹⁶ This is consistent with our previous practice of promoting the availability of mobile services through coverage obligations in spectrum licences. For example:
- a) When the 3G licences were awarded in 2000, they included an initial coverage obligation, which was subsequently increased further in 2011, following a direction by the Secretary of State to Ofcom;¹⁷
 - b) In 2013, we attached a coverage obligation to the 4G licence won by O2;¹⁸ and
 - c) In February 2015, we varied the licences of EE, H3G, O2, and Vodafone to implement an agreement reached between the Government and these operators in December 2014 to increase mobile coverage.¹⁹
- 2.47 The physical characteristics of the 700 MHz band mean it is particularly well-suited to achieving wide-area and indoor coverage. We have had the 700 MHz band in mind as a candidate band capable of use to improve mobile coverage. We have taken decisions over the past five years to clear the band with the express intention of making it available for mobile use to improve the coverage and quality of mobile services to consumers and citizens.
- 2.48 The four main mobile operators in the UK argued for and supported the clearance decisions that we, with the financial support of the UK Government²⁰, have taken, on the basis of their own predictions for the continued growth in demand for mobile data.

¹⁶ Ofcom’s statement of 25 February 2016, entitled “Making communications work for everyone Initial conclusions from the Strategic Review of Digital Communications”, paragraph 3.46. See https://www.ofcom.org.uk/_data/assets/pdf_file/0016/50416/dcr-statement.pdf

¹⁷ <https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2013/3g-coverage-compliance#F1>

¹⁸ See Section 5 of the Ofcom’s statement on the award of 800MHz and 2.6GHz spectrum; <http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/statement.pdf>

¹⁹ <https://www.ofcom.org.uk/about-ofcom/latest/media/media-releases/2015/mno-variations>

²⁰ In the 2015 Budget, the Government announced that it would provide up to £600 million funding to support the delivery of the change of use of the 700 MHz spectrum.

- 2.49 We also note that, unlike in previous auctions²¹, the current distribution of spectrum means that we consider it necessary to propose only limited measures in this award to promote and/or safeguard competition (see further below). As a result, we consider this supports our proposal to put particular emphasis on our aim of using the opportunities provided in this auction to improve mobile coverage.
- 2.50 In light of the above, our policy in this award is to seek to harness the wider social value that we believe can be unlocked through improved mobile coverage and quality.
- 2.51 Full details of our proposals are set out in section 4.

Other objectives

- 2.52 In addition to improving mobile coverage, we also intend to use this award to achieve a number of further policy objectives, as set out below.

Promoting competition

- 2.53 In accordance with our duties to promote competition, we want to ensure that consumers and businesses continue to benefit from strong competition in the provision of mobile services. We believe the UK market is generally operating well with continuing innovation and relatively low prices compared to other markets internationally.
- 2.54 As with the 2018 spectrum auction, we do not consider there are reasons for us to be concerned about the credibility of any of the four main MNOs in the UK in terms of their ability to compete effectively in the market.
- 2.55 We recognise that certain extreme outcomes of the award could give rise to concerns about the strength of that competition and we therefore propose to impose a cap of 37% on the proportion of mobile spectrum which a single MNO may hold after the award, consistent with the position we have taken in previous auctions. In practice, this would limit the spectrum acquisition of some operators and would mean that BT/EE, the operator with the largest current spectrum holdings, could not acquire more than 120 MHz of spectrum in this award.
- 2.56 We discuss competition issues in more detail in section 5.

Encouraging innovation and investment

- 2.57 We have also had regard to the economic and other benefits that may arise from the use of this spectrum, and the need to encourage the development of innovative services.
- 2.58 In addition to increasing capacity to meet demand for services delivered via existing mobile networks, there is the potential for this spectrum to be used for innovative 5G services. Timely development of 5G services has the potential to deliver significant benefits for UK

²¹ For example, during the 4G auction in 2013, we reserved some spectrum to seek to ensure there were four credible national wholesalers in the market after the auction. In our most recent auction of 2.3 and 3.4 GHz spectrum we considered it necessary to impose two spectrum caps in light of the risk that the auction outcome might otherwise give rise to a very asymmetric distribution of spectrum.

consumers and businesses, including superfast broadband, greatly expanded capacity and innovative new services.

- 2.59 Both the 700 MHz and the 3.6-3.8 GHz bands have properties and characteristics that make them particularly suitable for mobile broadband use, including latest technologies. We consider it important to make these bands available in a timely manner to meet consumer demand, particularly for increasing capacity for mobile broadband services, and to enable the industry to take advantage of innovation opportunities.

Auction design

- 2.60 The auction should be designed to best achieve our policy in this award of promoting optimal use of this spectrum in the interests of consumers and citizens by including coverage obligations. We are proposing to award the spectrum through a form of Combinatorial Clock Auction (CCA).
- 2.61 Ofcom seeks wherever possible to apply an auction design that meets its statutory duties without being unduly complicated. Participants should have confidence in the fairness of the process and the final outcome.
- 2.62 We recognise that imposing rules in an award and licence conditions to seek to increase coverage and promote competition places constraints on bidders, and that this may result in a different outcome compared to an award which included no such measures.
- 2.63 We consider we have struck an appropriate balance between these objectives, in light of our duties, and we believe our detailed proposals for the auction are appropriate and proportionate in the light of our statutory obligations.
- 2.64 We discuss the proposed auction design in more detail in section 7.

3. Legal framework

- 3.1 Our statutory duties derive from both European and domestic legislation, specifically from:
- a) The Common Regulatory Framework²² for electronic communications networks and services (the “**CRF**”), in particular, the Framework Directive and the Authorisation Directive;
 - b) Any relevant Decisions of the European Commission which bind the UK as to the use of the spectrum to be awarded; and
 - c) The Communications Act 2003 (the “**2003 Act**”) and the Wireless Telegraphy Act 2006 (the “**WT Act**”), which transpose the provisions of the directives referred to above into national law.
- 3.2 We note that the CRF is currently being revised, and that the European Electronic Communications Code (the “**Code**”) which will replace it, will shortly come into effect with an implementation deadline of December 2020. The UK Government has indicated that it currently intends to implement the Code, notwithstanding the UK’s exit from the EU. As such, we have had the new provisions of the Code in mind in making our proposals for this award, and as appropriate we make reference to the Code in that context in this document.

The Common Regulatory Framework

The Framework Directive

- 3.3 Article 8 of the Framework Directive sets out the objectives which national regulatory authorities must take all reasonable steps to achieve. These include:
- a) the promotion of competition in the provision of electronic communications networks and services by, amongst other things, ensuring there is no distortion or restriction of competition in the electronic communications sector and encouraging efficient use and effective management of radio frequencies (Art. 8(2)); and
 - b) contributing to the development of the internal market by, amongst other things, removing obstacles to the provision of electronic communications networks and services at a European level, and encouraging the interoperability of pan-European services (Art. 8(3)).
- 3.4 In pursuit of these policy objectives, Article 8 requires national regulatory authorities to apply objective, transparent, non-discriminatory and proportionate regulatory principles by, among others:

²² The Common Regulatory Framework comprises the Framework Directive (Directive 2002/21/EC), the Authorisation Directive (Directive 2002/20/EC), the Access Directive (Directive 2002/19/EC), the Universal Service Directive (Directive 2002/22/EC) and the Directive on privacy and electronic communications (Directive 2002/58/EC), as amended by the Better Regulation Directive (Directive 2009/140/EC).

- a) ensuring that, in similar circumstances, there is no discrimination in the treatment of undertakings providing electronic communications networks and services;
 - b) safeguarding competition to the benefits of consumers and promoting, where appropriate, infrastructure-based competition; and
 - c) promoting efficient investment and innovation in new and enhanced infrastructures.
- 3.5 Article 8 also requires Member States to ensure that, in carrying out their regulatory tasks, national regulatory authorities take the utmost account of the desirability of making regulations technologically neutral.
- 3.6 Article 9 of the Framework Directive requires Member States to ensure the effective management of radio frequencies for electronic communications services in accordance with Article 8, and to ensure that spectrum allocation used for electronic communications services and issuing general authorisations or individual rights of use of such radio frequencies are based on objective, transparent, non-discriminatory and proportionate criteria. Article 9 also requires Member States to promote the harmonisation of use of radio frequencies across the Community, consistent with the need to ensure effective and efficient use of frequencies. It further requires Member States to ensure technology and service neutrality.

The Authorisation Directive

- 3.7 Article 5 of the Authorisation Directive provides that where it is necessary to grant individual rights of use of radio frequencies, Member States must grant such rights through open, objective, transparent, non-discriminatory and proportionate procedures, and in accordance with the provisions of Article 9 of the Framework Directive. When granting those rights, Member States are required to specify whether they can be transferred by the holder, and if so, under which conditions.
- 3.8 Article 6 of the Authorisation Directive provides that rights of use for radio frequencies may be subject only to the conditions listed in the annex to the directive. Part B of the annex, which sets out conditions which may be attached to such rights of use, includes an obligation to provide a service or to use a type of technology for which the rights of use for the frequency has been granted, including, where appropriate, coverage and quality requirements, as well as conditions relating to the effective and efficient use of frequencies.
- 3.9 Article 7 of the Authorisation Directive provides that where Member States decide to limit the number of rights of use to be granted for radio frequencies, they must, among other things, give due weight to the need to maximise benefits for users and to facilitate the development of competition.
- 3.10 The legal duties imposed on the UK by the Framework and Authorisation Directives are transposed into UK law and given effect to by the 2003 Act and the WT Act (see below).

Directive 2009/140/EC which amended the CRF

- 3.11 The CRF was amended in 2009 after a periodic review by the European Commission. Recital 24 to the amending Directive²³ set out that:

“Radio frequencies should be considered a scarce public resource that has an important public and market value. It is in the public interest that spectrum is managed as efficiently and effectively as possible from an economic, social and environmental perspective, taking account of the important role of radio spectrum for electronic communications, of the objectives of cultural diversity and media pluralism, and of social and territorial cohesion.”

The Code

- 3.12 The new Code, due to come into force by December 2020, also makes clear that Member States should pursue connectivity objectives in terms of achieving widespread access to and take-up of very high capacity networks for all citizens and businesses.²⁴ This connectivity objective translates, on the one hand, into aiming for the highest capacity networks and services economically sustainable in a given area, and, on the other hand, into pursuing territorial cohesion, in the sense of convergence in capacity available in different areas.

- 3.13 Recital 109 notes that:

“Ensuring widespread connectivity in each Member State is essential for economic and social development, participation in public life and social and territorial cohesion. As connectivity and the use of electronic communications become an integral element to European society and welfare, Member States should strive to ensure Union-wide wireless broadband coverage. Such coverage should be achieved by relying on the imposition by Member States of appropriate coverage requirements, (...) measures should aim to ensure the release of sufficient radio spectrum in bands which are particularly valuable assets for the cost-efficient deployment of wireless networks with universal coverage, in particular indoors. (...) Seamless coverage of the territory as well as connectivity across Member States should be maximised and reliable, with a view to promoting in-border and cross-border services and applications such as connected cars and e-health.”

- 3.14 Recital 229 further explains that in areas where the market would not deliver broadband internet access, attaching coverage obligations to the rights of use for radio spectrum appears more cost effective and less market-distortive than universal service obligations.

²³ Directive 2009/140/EC of the European Parliament and of the Council of 25 November 2009 amending Directives 2002/21/EC on a common regulatory framework for electronic communications networks and services, 2002/19/EC on access to, and interconnection of, electronic communications networks and associated facilities, and 2002/20/EC on the authorisation of electronic communications networks and services.

²⁴ See recital 23.

- 3.15 Article 45(2) of the Code, which concerns management of spectrum, requires Member States to promote the harmonisation of use of radio spectrum, consistent with the need to ensure effective and efficient use thereof and in pursuit of benefits for the consumer, by amongst other things “pursuing wireless broadband coverage of their national territory and population at high quality and speed”. Part D of annex I, which is the equivalent of the current annex to the Authorisation Directive and sets out the conditions which may be attached to rights of use for radio spectrum, maintains the inclusion of obligations to provide a service or to use a type of technology, including where appropriate, coverage and quality of service requirements.

European Commission decisions relevant to the 700 MHz and 3.6-3.8 GHz spectrum

The 700 MHz spectrum

- 3.16 The 700 MHz spectrum is the upper part of the 470-790 MHz frequency band (the “**UHF band**”) which is currently used for terrestrial broadcasting and wireless audio PMSE use.
- 3.17 On 17 May 2017, the European Parliament and the Council adopted Decision 2017/899 (the “**2017 UHF Decision**”) ²⁵, which requires Member States to repurpose the 700 MHz frequency band from its current TV broadcasting and PMSE use to new mobile broadband use by 30 June 2020. In doing so, Member States must apply the technical conditions laid down in the Commission implementing decision adopted on 28 April 2016 to harmonise the technical conditions of use and band plan for the 700 MHz band. ²⁶
- 3.18 Art. 3(1) of the 2017 UHF Decision provides that:

When Member States authorise the use of or amend existing rights to use the 700 MHz frequency band, they shall take due account of the need to achieve the target speed and quality objectives set out in Article 6(1) of Decision No 243/2012/EU, including coverage in predetermined national priority areas where necessary, such as along major terrestrial transport paths, for the purpose of allowing wireless applications and European leadership in new digital services to contribute effectively to Union economic growth. Such measures may include conditions to facilitate or encourage the sharing of network infrastructure or spectrum in accordance with Union law.” ²⁷

- 3.19 The target speed and quality objectives set out in art. 6(1) of Decision No 243/2012/EU ²⁸, which Art. 3(1) of the 2017 UHF Decision refers to, include “*achieving the target for all*”

²⁵ Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union: <http://eurlex.europa.eu/legalcontent/EN/TXT/?qid=1515598100425&uri=CELEX:32017D0899>

²⁶ Commission Implementing Decision (EU) 2016/687 of 28 April 2016 on the harmonisation of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2016.118.01.0004.01.ENG

²⁷ See also Recital 9 of the 2017 UHF Decision.

²⁸ Decision 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multiannual radio spectrum policy programme: <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32012D0243>

citizens to have access to broadband speeds of not less than 30 Mbps by 2020". Recital 9 to the 2017 UHF Decision specifies that such target includes both indoor and outdoor coverage.

- 3.20 In complying with Art. 3(2) of the 2017 UHF Decision, Member States are required to *"assess the need to attach conditions to the rights of use for frequencies within the 700 MHz frequency band and, where appropriate, shall consult relevant stakeholders"*.²⁹

The 3.6-3.8 GHz spectrum

- 3.21 On 21 May 2008, the European Commission adopted Decision 2008/411/EC which sought to harmonise the conditions for the availability and efficient use of the 3.4-3.8 GHz frequency band for terrestrial systems capable of providing electronic communications services in the EU. The Decision provided that Member States should designate, by 1 January 2012, the 3.6-3.8 GHz band on a non-exclusive basis for terrestrial communications networks in compliance with the technical parameters set out in the annex to the Decision.
- 3.22 On 2 May 2014, the European Commission adopted Decision 2014/276/EU, which amended Commission Decision 2008/411/EC, primarily in relation to the technical conditions in compliance with which the band should be made available.³⁰

UK national law

The Communications Act 2003 ("the 2003 Act")

- 3.23 Ofcom's principal duties under section 3 of the 2003 Act are:
- a) to further the interests of citizens in relation to communications matters; and
 - b) to further the interests of consumers in relevant markets, where appropriate, by promoting competition.
- 3.24 By virtue of our principal duties, we are required to secure, amongst other things, the optimal use for wireless telegraphy of the electro-magnetic spectrum (2003 Act, s. 3(2)(a)) and the availability throughout the UK of a wide range of electronic communications services (2003 Act, s. 3(2)(b)).
- 3.25 In performing our duties we must also have regard to certain matters as appear to us to be relevant in the circumstances, including:
- a) the desirability of promoting competition in relevant markets (2003 Act, s. 3(4)(b));
 - b) the desirability of encouraging investment and innovation in relevant markets (2003 Act, s. 3(4)(d));
 - c) the desirability of encouraging the availability and use of high speed data transfer services throughout the UK (2003 Act, s. 3(4)(e));

²⁹ Art. 3(2) of the 2017 UHF Decision.

³⁰ The EC Decision (as amended) has been implemented into UK law by way of Statutory Instrument 2016 No. 495.

- d) the different needs and interests of all persons who may wish to make use of the electro-magnetic spectrum (2003 Act, s. 3(4)(f)); and
 - e) the different interests of persons in the different parts of the UK and persons living in rural and in urban areas (2003 Act, s. 3(4)(l)).
- 3.26 In performing our duties, we are required under section 3(3) of the 2003 Act to have regard in all cases to the principles under which regulatory activities should be transparent, accountable, proportionate, consistent and targeted only at cases in which action is needed.
- 3.27 Section 4 of the 2003 Act requires Ofcom to act in accordance with the six Community requirements, which give effect to the requirements of Article 8 of the Framework Directive. In summary, the Community requirements are requirements:
- a) to promote competition in communications markets;
 - b) to ensure that Ofcom contributes to the development of the European internal market;
 - c) to promote the interests of all European Union citizens;
 - d) to act in a manner which, so far as practicable, is technology neutral;
 - e) to encourage, to the extent Ofcom considers it appropriate, the provision of network access and service interoperability for the purposes of securing efficiency and sustainable competition in communications markets and the maximum benefit for the customers of communications network and services providers; and
 - f) to encourage such compliance with certain international standards as is necessary for facilitating service interoperability and securing freedom of choice for the customers of communications providers.

The Wireless Telegraphy Act 2006 (“the WT Act”)

Duties imposed by the WT Act

- 3.28 In carrying out our spectrum functions, we have a duty under section 3 of the WT Act to have regard in particular to: (i) the extent to which the spectrum is available for use or further use for wireless telegraphy, (ii) the demand for use of that spectrum for wireless telegraphy and (iii) the demand that is likely to arise in future for the use of that spectrum for wireless telegraphy.
- 3.29 We also have a duty to have regard, in particular, to the desirability of promoting: (i) the efficient management and use of the spectrum for wireless telegraphy, (ii) the economic and other benefits that may arise from the use of wireless telegraphy, (iii) the development of innovative services and (iv) competition in the provision of electronic communications services (WT Act, s. 3(2)).

Allocation of spectrum by auction

- 3.30 Ofcom may allocate spectrum by way of auctions having regard to the desirability of promoting the optimal use of spectrum (WT Act, s. 14). In making auction regulations, Ofcom must satisfy itself that the criteria for spectrum allocation are:
- a) objectively justifiable in relation to the frequencies to which they relate;
 - b) not such as to discriminate unduly against particular persons;
 - c) proportionate to what they are intended to achieve; and
 - d) in relation to what they are intended to achieve, transparent (WT Act, s.14(3B)).
- 3.31 Auction regulations may make provisions with respect to the grant of the relevant licences and also the terms, provisions and limitations subject to which such licences are granted (WT Act, s. 14(2) and s. 14(3)(h)).

Licence conditions

- 3.32 S.9(1A) of the WT Act confirms that the terms, provisions and limitations of a licence for the use of spectrum for the provision of an electronic communications network or service must fall within Part B of the annex to the Authorisation Directive as set out above.
- 3.33 The terms, provisions and limitations of a spectrum licence must not duplicate the obligations already imposed on the licensee by the general conditions set by Ofcom under section 45 of the Communications Act (WT Act, s. 9(6)). Neither the current general conditions nor the revised general conditions that will come into force on 1 October 2018³¹ include any of the obligations that we are proposing to attach to the 700 MHz or 3.6–3.8 GHz licences.
- 3.34 Under section 9(7) of the WT Act, Ofcom may only impose terms, provisions and limitations which are:
- a) objectively justified in relation to the network and services to which they relate;
 - b) not unduly discriminatory;
 - c) proportionate to what they are intended to achieve; and
 - d) transparent in relation to what they are intended to achieve.

Impact assessments

Impact assessment under section 7 of the 2003 Act

- 3.35 The analysis presented in this document, including its annexes, constitutes an impact assessment as defined in section 7 of the 2003 Act.

³¹ The general conditions of entitlement: <https://www.ofcom.org.uk/phones-telecoms-and-internet/information-for-industry/telecoms-competition-regulation/general-authorisation-regime>

- 3.36 Section 7 of the 2003 Act provides that where we are proposing to do anything for the purposes of or in connection with the carrying out of our functions, and it appears to us that the proposal is important, we are required to carry out and publish an assessment of the likely impact of implementing the proposal, or a statement setting out our reasons for thinking that it is unnecessary to carry out such an assessment. Where we publish such an assessment, stakeholders must have an opportunity to make representations to us about the proposal to which the assessment relates.
- 3.37 Impact assessments provide a valuable way of assessing different options for regulation and showing why the preferred option was chosen. They form part of best practice policy-making. As a matter of policy, Ofcom is committed to carrying out impact assessments in relation to the great majority of our policy decisions.³²

Equality impact assessment

- 3.38 Ofcom is required by statute to assess the potential impact of all our functions, policies, projects and practices on the following equality groups: age, disability, gender, gender reassignment, pregnancy and maternity, race, religion or belief and sexual orientation.³³ We refer to groups of people with these protected characteristics as ‘equality groups’.
- 3.39 We fulfil these obligations by carrying out an Equality Impact Assessment (“EIA”), which examines the potential impact our proposed policy is likely to have on people, depending on their personal circumstances. EIAs also assist us in making sure that we are meeting our principal duty of furthering the interests of citizens and consumers, regardless of their background and identity.
- 3.40 We have not considered it necessary to carry out separate EIAs in relation to our additional equality duties in Northern Ireland, regarding religious belief and political opinion. This is because we anticipate that our proposals will not have a differential impact on any equality group in Northern Ireland compared to consumers in general.

Summary of our impact assessments

- 3.41 In summary, we consider that our proposals would have a positive impact for consumers in the UK, particularly people in rural areas. This is because the coverage obligations that we are proposing to include in the auction would principally benefit those living and working in rural areas (which do not currently have the same availability and quality of mobile coverage as urban areas), but also commuters and tourists in these regions. We do not believe that our proposals would have a detrimental impact on any of the relevant equality groups.

³² For further information about our approach to impact assessments, see Ofcom’s document “Better policy-making: Ofcom’s approach to impact assessment”, 21 July 2005:

https://www.ofcom.org.uk/_data/assets/pdf_file/0026/57194/better_policy_making.pdf

³³ As defined in the Equality Act 2010.

4. Coverage obligations

- 4.1 This section sets out the coverage obligations we propose to include in this award, taking account of stakeholders' responses to the initial proposals for coverage set out in our March 2018 consultation.³⁴
- 4.2 In summary, we are proposing to include two identical coverage obligations in the award. These would require that within four years of the award licence holders with a coverage obligation will:
- deliver good quality mobile coverage outdoors to at least 90% of the UK landmass;
 - deploy a minimum of 500 new wide area macro sites;
 - provide new coverage in areas where at least 140,000 premises are located.
- 4.3 Our proposals are intended to improve the quality of mobile coverage in most of the rural places where people live and travel around. Our proposed obligations focus on good quality mobile broadband coverage, which provides consumers with good quality voice and data services.
- 4.4 We are proposing to use a coverage threshold based on a predicted signal strength that should ensure that when consumers are outdoors, they have a very high probability of making a 90 second phone call and of achieving minimum download speeds of at least two megabits per second. This minimum quality level supports most commonly-used data services, including video streaming - though faster speeds will be available much of the time.

The mobile coverage landscape and our proposals

Current mobile coverage is not good enough

- 4.5 We are concerned that the geographic availability of mobile services, particularly high quality data services, is not currently good enough across the UK. We have an ambition to see universal coverage of communications services and we are working with others, including governments and industry where necessary, to progress this.
- 4.6 As of today, quality geographic coverage remains very far from comprehensive, with coverage in rural areas particularly poor. This includes a core of around 250-450,000 homes and businesses which are currently without even outdoor good quality geographic coverage from an individual operator in their area.³⁵
- 4.7 Consumers in these areas will typically experience frustrations with their mobile coverage today (for example, intermittent internet connectivity, with sluggish browsing, and dropped calls) as they move around. A good service from all operators is only available in

³⁴ Improving Mobile Coverage, Ofcom, <https://www.ofcom.org.uk/consultations-and-statements/category-2/700-mhz-coverage-obligations>

³⁵ Connected Nations 2018, data based on information provided by the mobile operators in May 2018.

66% of the UK. Coverage of the rural road network is also patchy: most operators do not provide a good quality outdoor service for around 10% of B roads.

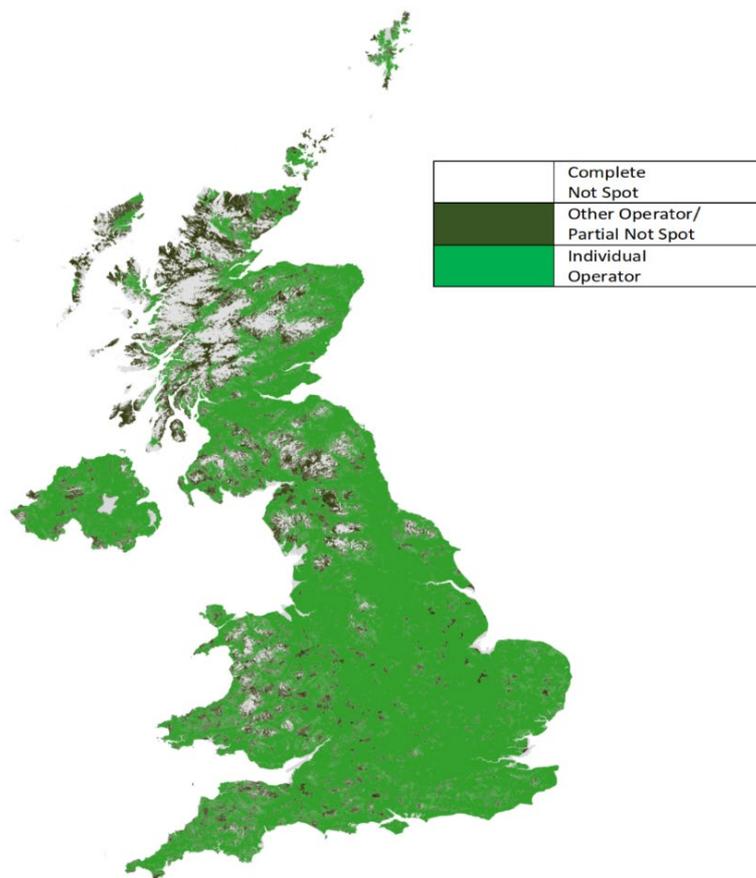
Figure 4.1: Current levels of voice and data coverage (September 2018)

	Voice Coverage			4G Data Coverage		
	Landmass	Outdoor premises	Indoor premises	Landmass	Outdoor premises	Indoor premises
BT/EE	85.0%	99.4%	95.8%	84.4%	99.1%	88.4%
O2	90.4%	99.8%	99.1%	74.4%	98.9%	94.8%
H3G	84.8%	99.5%	95.9%	78.4%	98.6%	89.4%
Vodafone	90.4%	99.8%	98.6%	78.6%	99.0%	93.7%

Source: Ofcom Connected Nations 2018

- 4.8 As shown in Figure 4.1, there remains, for each operator, a residual core of around 1% of premises across the UK without even outdoor 4G coverage in their area. This is reflected in significantly lower levels of good quality coverage across the wider UK landmass. Indoor coverage levels are significantly lower due to the higher signal strength required to penetrate walls and windows, although we recognise that other solutions such as WiFi and voice-over-WiFi may provide alternatives for consumers when at home or at work.
- 4.9 Some of these areas may have access to a patchy, poor quality mobile service, where more than one in three calls will fail, whilst some will have no coverage at all. Our proposals are intended to improve the quality of mobile coverage in most of the rural places where people live, work and visit.
- 4.10 The map below (Figure 4.2) shows the levels of good outdoor coverage from an example operator, and the gaps in its coverage (including the ‘partial not-spot’ areas where a patchwork quilt of coverage is available from other operators, but not available to customers of that network).

Figure 4.2 Example of UK mobile broadband coverage from one mobile operator (and areas where other operators provide a service)



- 4.11 These ‘partial not-spots’ largely align with the areas where there is some further, patchy coverage available from the operators who are not providing good coverage in the area. These partial not-spots, where only patchy coverage is available from individual operators, also contain the majority of homes and businesses without good coverage. Whilst individual consumers may have some coverage from an operator in the place they live, people living and travelling around in these areas will not enjoy a contiguous good quality service.

Why good quality coverage is important

- 4.12 Having access to good quality mobile coverage provides significant benefits to citizens and consumers. We set this out in greater detail in annex 11. Without good 4G coverage, rural consumers are unable to participate in various activities which many urban consumers take for granted. For example, they may not enjoy consistent, good quality voice calls and access to a reliable data connection capable of supporting services from email and WhatsApp through to smooth internet browsing, reliable access to online maps and video services.

- 4.13 In areas with poorer quality coverage, consumers are unlikely to be able to access data-intensive applications and may experience delays and buffering with basic internet applications. Whilst mobile coverage in the UK has improved over recent years through a combination of commercial investment, public policy and regulatory interventions, it is still not meeting people's expectations.
- 4.14 Ofcom research indicates that 20% of rural consumers are not satisfied with their mobile network experience.³⁶ We consider the shortfall in contiguous, good quality geographic coverage is a key driver of consumer frustration, leading to poor coverage experience in places they travel through and visit.
- 4.15 Typically, we expect a consumer will gravitate towards the operator that provides the best coverage in the places they spend the most time. We have developed the mobile coverage information we provide to consumers, including our mobile coverage checker app, to support informed consumer choice. However, frustrations often affect people as they move about in different places, where no one operator provides comprehensive coverage.
- 4.16 Consumers who want to enjoy comprehensive mobile coverage therefore do not have a clear choice of one operator who can provide this contiguous experience. In addition, some consumers may have lower awareness of the coverage provided by different mobile operators, or face other difficulties switching, which might prevent them from moving to a different mobile operator with better coverage.
- 4.17 Even where good outdoor coverage is available, it can still lead to frustrations in consumer experience, especially indoors and in vehicles. For example, only 18% of premises in rural areas receive good quality indoor coverage from all four operators, whilst each individual operator does not provide good quality indoor coverage to more than half a million rural homes and businesses.
- 4.18 A large proportion of rural consumers will therefore experience coverage of a poorer quality i.e. where the signal falls below the strength necessary to achieve consistent good quality coverage. Given the importance consumers place on mobile coverage, improving the quality and availability of a good mobile service is one of our top priorities.

Levers for securing comprehensive mobile coverage

- 4.19 We have considered whether competition itself would be likely to result in comprehensive mobile coverage in the UK, or whether some form of intervention to improve mobile coverage is required.³⁷
- 4.20 Competition is an important driver of investment in mobile networks. However, building and running the mobile sites necessary to extend coverage in areas of lower population density is expensive and may be unprofitable, given these are not densely populated areas.

³⁶ Ofcom, Customer Service Tracker Survey 2018, Question M4. And how satisfied are you overall with the reception or signal strength that you get on your mobile phone service. Available at https://www.ofcom.org.uk/data/assets/pdf_file/0021/112287/Customer-service-tracker-2018-data-tables.pdf Table 25.

³⁷ See also annex 11.

There are therefore limits to the extent to which competition is likely to drive the expansion of mobile coverage.

- 4.21 Our assessment, informed by information given to us by the mobile operators, is that by the time of the award of the 700 MHz bands, industry is likely to be reaching towards the upper bounds of the coverage that commercial investment driven by competition will deliver (around 82-84% of the UK landmass).
- 4.22 We consider that improving the availability of good mobile coverage beyond the levels likely to be delivered by competition alone would bring significant social benefits to the UK.³⁸ Consequently, we think that intervention is necessary, and it is appropriate to seek to improve the level and quality of coverage that exists today.
- 4.23 Ofcom alone does not hold the levers necessary to fully address the coverage deficit, and we are therefore engaged with others in a package of work to improve coverage, working particularly closely with UK and devolved governments. This work has included:
- UK and devolved government working to simplify the planning regime;
 - publicly funded intervention in Scotland and the potential for a similar intervention in Wales³⁹;
 - work to improve coverage on railways;
 - Ofcom’s policy in relation to mobile repeaters⁴⁰; and
 - Ofcom’s advice to DCMS in relation to roaming, infrastructure sharing and potential further cost-reduction measures.⁴¹
- 4.24 Ofcom has also been undertaking work to help consumers get the best coverage experience available, and provide clear information on good quality coverage to promote consumer choice, for example, with our ‘mobile checker app’.
- 4.25 One way that Ofcom can act to contribute to improvements in mobile coverage is to set coverage obligations in the spectrum licences we award. In 2013, we used this lever to place a roll-out requirement on one licensee (O2) to bring improved 4G coverage to 98% of the population.
- 4.26 We think it is appropriate for Ofcom to exercise its functions, in light of our duties, to seek to secure improved mobile coverage in poorly served rural areas. We recognise that, whilst our proposals would make a significant difference, they may not provide a comprehensive solution to all mobile coverage issues. We will continue to work with the industry and UK and devolved Governments on further measures where they are required.
- 4.27 We believe the forthcoming award provides us with an important opportunity to improve the availability of mobile services in poorly served parts of the UK. The physical

³⁸ See also annex 11.

³⁹ The Scottish Government, 2016, Mobile Action Plan <https://beta.gov.scot/publications/mobile-action-plan/>
The Welsh Government, 2017, Mobile Action Plan [http://gov.wales/topics/science-and-](http://gov.wales/topics/science-and-technology/digital/infrastructure/mobile-action-plan/?lang=en)

[technology/digital/infrastructure/mobile-action-plan/?lang=en](http://gov.wales/topics/science-and-technology/digital/infrastructure/mobile-action-plan/?lang=en)

⁴⁰ <https://www.ofcom.org.uk/about-ofcom/latest/features-and-news/mobile-phone-repeaters>

⁴¹ Ofcom’s Advice to Government of 14 September 2018 on “Further options for improving mobile coverage”;

<https://www.ofcom.org.uk/phones-telecoms-and-internet/coverage/advice-government-improving-mobile-coverage>

characteristics of the 700 MHz band mean it is particularly well-suited to achieving wide-area coverage across the UK landmass.

- 4.28 As discussed in Section 2, we have had the 700 MHz band firmly in mind as a band suitable for improving mobile coverage in rural areas for the benefit of consumers and citizens, and we have taken decisions over the past five years to clear the band with the express intention of making it available for such use. We stated in our 2015 Digital Communications Review that we were minded to include coverage obligation proposals for this award. We then published proposals in March 2018 to include coverage obligations in this award.
- 4.29 In our initial consultation, we identified a policy priority to focus on improving rural coverage (in line with consumers' concerns) by seeking to improve the extent of good quality 4G coverage across the UK landmass. In doing this, we explained that we wanted to improve coverage in places people live, work and travel.

Summary of our revised proposals

- 4.30 We have taken account of the responses to our March 2018 consultation, and have undertaken further assessment in light of both those responses and further evidence we have collected, in order to put together the proposals that we now make in this consultation.
- 4.31 In summary, we are proposing to include two identical coverage obligations in the award. These would require that, within four years of the award, obligation holders will:
- deliver good quality 4G mobile coverage outdoors to at least 90% of the UK landmass;
 - deploy a minimum of 500 new wide area coverage sites; and
 - provide new coverage in areas where at least 140,000 premises are located.
- 4.32 We are proposing that an operator may use any mobile spectrum to deliver this obligation, so that an operator wishing to bid for 3.6-3.8 GHz, but not 700 MHz, could still bid for a coverage obligation if it wished - and deliver it using alternative spectrum bands, e.g. 800 MHz.

The 'premises requirement'

- 4.33 We are proposing to include a requirement in the obligations, which we are referring to as the 'premises requirement', for the winning bidder to improve outdoor coverage for at least 140,000 premises to which it does not currently provide good quality coverage.
- 4.34 The purpose of the premises requirement is to ensure that the additional coverage provided under the obligations would be delivered in places where people live, work and visit - and therefore result in meaningful benefits to citizens and consumers. We set out in annex 14 why we consider this a reasonable requirement for an operator to meet.

The 'new sites requirement'

- 4.35 We are also proposing a requirement to deploy a minimum of 500 new wide area macro sites in order to help achieve all the wider benefits of extending coverage, including overspill benefits of better indoor and in-vehicle coverage (which we do not propose to set as a requirement of the obligation).⁴² We expect that these new sites would need to be macro sites in rural areas for which we intend to specify minimum requirements as part of our compliance methodology.⁴³
- 4.36 We have estimated that a typical operator will need to deploy between 500 and 1,000 new sites to meet the coverage obligation, as set out in annex 14. One operator might need to deploy fewer sites (around 300 to 700).
- 4.37 We recognise that operators have other means of delivering some coverage improvements from existing infrastructure, including by operating at higher powers than they currently do on all sites. Whilst there may be cases where this is an appropriate way of improving coverage, we also consider that were the majority of the obligation to be delivered in this way, there is a risk that consumers will not see noticeable improvements in the service they receive.
- 4.38 The improvements would tend to be incremental rather than transformative, and wider benefits of improved in-building and in-vehicle coverage (which are described in more detail in annex 11) that would be delivered from building new masts would be unlikely to materialise. As a result, the benefits would not be as large as the benefits that we are seeking to achieve. We therefore consider that a requirement to deploy a minimum number of new macro sites is an appropriate step to ensure the costs and benefits of the obligation are balanced, and appropriate to the maximum discount we are proposing to offer.

Coverage requirements for each UK nation

- 4.39 Our proposals continue to include specific coverage requirements for each nation:
- England - at least 90% coverage;
 - Northern Ireland - at least 90% coverage;
 - Scotland - at least 74% coverage; and
 - Wales - at least 83% coverage.
- 4.40 These proposals are designed to ensure that the benefits of our intervention are spread across the whole of the UK, with a focus on ensuring that those nations with the worst coverage today see the largest increases. We discuss further our proposals for coverage requirements in each of the UK Nations later in this section.

⁴² Whilst we have considered the case for specifying our expected overspill benefits in the obligations, we do not think this would be appropriate given the significant variations in building (and vehicle) penetration losses on the ground.

⁴³ To ensure that these new sites support wide area coverage in rural areas, we provisionally consider that we will include a requirement that new sites are more than 1-2 kilometres from an individual operators existing network.

Timescales

- 4.41 We are proposing a four-year timescale for meeting the proposed obligations, in order to mitigate the risk that operators would be discouraged from acquiring an obligation because of the associated timescale pressures. We would however expect to see significant improvements in coverage in advance of the four-year deadline.

Compliance

- 4.42 We plan to assess compliance with the obligations with reference to a model that we will make available to operators, benchmarked against their own view of where they provide coverage today.
- 4.43 Our initial view is that coverage which an obligated operator offers through a mutually agreed roaming arrangement onto a host network could count towards fulfilment of these coverage obligations - provided the service onto which the obligated operator roams meets the requirements of our proposed obligations. We consider that this is something an obligation holder may wish to explore, either with another operator, or with any other locally provided network where a roaming arrangement could deliver the obligation.

How our proposals will improve mobile coverage

- 4.44 Our proposed coverage obligations are intended to ensure that consumers can access good quality mobile services more widely than they can today, with a focus on places people regularly go.
- 4.45 To ensure this is the case, we are minded to require that operators deliver coverage at signal strengths which support good quality coverage. We set out in annex 14 why we believe a good quality data services of 2mbps and a very high call success rate is required, and what signal strength we consider supports this service.⁴⁴ It is important to note that these requirements reflect the minimum service available to a user in a given location, and that better coverage (including faster download speeds) would be available much of the time (for example if the cell is lightly loaded or if the user is not at the edge of the cell).
- 4.46 Mobile operators would have a degree of flexibility to choose the locations where they provide this improved coverage to meet the proposed obligations. This means that the improvement could take several forms, including:
- providing good outdoor mobile coverage (e.g. good 4G) where 2G (voice and SMS) or 3G (lower quality data) or poor quality 4G services are already available; or
 - providing good outdoor mobile coverage where there is no coverage today.
- 4.47 The investment an obligated operator would make to meet one of our proposed coverage obligations is likely to focus on improving the quality and contiguity of coverage in frequented rural areas, so the main effect of the obligation is likely to be improvement of

⁴⁴ Note that as set out in Annex 14, we consider that a high confidence level of more than 95% is required for both these voice and data services.

the quality of service where it is currently patchy. This reflects our view of the nature of consumer experience frustrations, and the ‘always on’ quality that consumers want – meaning they expect and rely upon coverage in regularly visited places.⁴⁵ The ‘premises requirement’ will safeguard a significant part of the coverage improvements we envisage happening in these places.

- 4.48 A mobile operator acquiring an obligation would need to deploy 4G (or equivalent newer services) on at least 500 new mobile masts in order to fulfil the obligation. Due to the technical characteristics of mobile services, we expect that some areas near these masts will also experience improved indoor 4G coverage (and potentially improved in-vehicle coverage), even though we are not proposing that this would itself be a requirement of the obligations.
- 4.49 We also anticipate that the obligations are likely to deliver increases in B-road and minor road coverage, benefitting rural consumers as they travel between places where people live and work.
- 4.50 We also think it is likely that our obligations will deliver some completely new coverage in the places to which no mobile network currently provides coverage – so-called ‘total not-spots’ – particularly where these are regularly frequented areas.
- 4.51 However, some problems are likely to remain unresolved. Our proposals are unlikely to deliver significant improvements in rail coverage, where deep cuttings will require specific interventions to deliver the signal needed inside the carriage (although our proposed ‘premises requirement’ may see some improvements in outdoor coverage along suburban rail routes). They are also unlikely to provide a complete solution for the small but significant number of UK homes (c10,000) which we estimate to have absolutely no mobile coverage in their vicinity, which tend to be scattered across disparate remote locations. Further measures will be needed to improve these coverage problems.

Ofcom’s assessment in light of stakeholders’ comments

- 4.52 In March, we consulted on proposals for up to two geographic coverage obligations to serve 92% of the UK landmass, and a further obligation to improve coverage for up to 60% of rural premises with poor indoor coverage.
- 4.53 We took account of all the responses received in developing our revised proposals for including two, rather than three, coverage obligations in the auction, and for setting the requirement to provide good quality mobile broadband coverage to a minimum level of 90% of the UK landmass (with additional requirements around premises coverage and new masts), rather than 92%. We set out our more detailed analysis of key issues raised, including our assessment of a premises obligation, and the prospect of a roaming obligation, in more detail in annex 17.

⁴⁵ Jigsaw, Mobile Coverage Qualitative Research 2017, p9

https://www.ofcom.org.uk/data/assets/pdf_file/0021/108129/jigsaw-mobile-coverage-qualitative-research.pdf

- 4.54 We have revised our high-level modelling to estimate the costs involved in meeting our proposals, and undertaken a further assessment of the benefits. Our revised analysis suggests that a geographic coverage obligation set at 90% of the UK landmass is likely to deliver social benefits which would be at least as large as the underlying costs.

We believe 90% good quality geographic coverage is the appropriate level for the obligation

- 4.55 In our March 2018 consultation, we set out a qualitative assessment of the benefits of improving coverage without trying to quantify them. As noted above, we received a range of different views from stakeholders as to the proportionality of our March 2018 consultation proposals. Many respondents agreed there were significant benefits from enhanced coverage. However, other respondents questioned our analysis of the economic benefits of the proposed coverage obligations and the proportionality of the circa £300m investment we envisaged for each obligation.
- 4.56 The level at which we can specify the obligations is constrained by the costs of meeting them, compared with the value of spectrum and the benefits we think will be delivered. We have considered the costs and benefits of improving mobile coverage in order to reach our proposals for the obligations. In doing this, we have carried out analysis to estimate both:
- the total benefits and costs of meeting our proposed obligations; and
 - the incremental benefits and costs of increasing mobile coverage to different levels.
- 4.57 We think it is appropriate to propose obligations up to a level where the additional benefits we expect to arise from that additional coverage are likely to exceed the additional cost of delivering the new or improved coverage.
- 4.58 Our provisional view is that a coverage obligation requiring an operator to provide good coverage to 90% of the UK's landmass is the most stretching obligation that it is appropriate to include in the auction - taking account of our view of the likely benefits and costs of such an obligation. This is lower than the 92% level we proposed in March 2018.
- 4.59 Our modelling indicates that the costs for operators of moving beyond this, from 90% to 92% coverage, are likely to become significantly higher, and the benefits (in terms of premises and roads covered) significantly lower. We therefore consider it unlikely that incremental benefits associated with a level of 92% would be large enough to justify the incremental costs.
- 4.60 An important factor in our revised view is our treatment of the Extended Area Service sites being built by the Home Office to support its Emergency Service Network contract.⁴⁶ In March, we considered that these were one of a number of factors that might reduce the costs of coverage for operators and support a 92% threshold. We have now taken account

⁴⁶ The Home Office is undertaking a programme of work to develop an Emergency Service Network (ESN). This includes sites being delivered by EE to meet its contractual requirements ('the ESN sites'), a subset of which we understand are expected to be returned to the Home Office at the end of the ESN contract. Separately, the Home Office is itself building around 300 new sites to improve coverage in remoter areas, known as the Extended Area Service sites ('the EAS sites').

of concerns from operators that, because these sites do not yet exist and their ability to access them is unclear, they may not be able to rely on them when bidding for an obligation.

- 4.61 We have also taken further account of their relatively remote location, which might mean the benefits of adding coverage in some of these locations are likely to be less than in more regularly frequented areas. Our provisional view is therefore that we should not account for these sites in the baseline from which we assess coverage today, and that consequently we should not include coverage from these sites in our compliance process. This would mean that an operator acquiring an obligation and deploying on these sites commercially could deliver more than 90% coverage for consumers.
- 4.62 As noted, our proposals now include two additional requirements: namely, to cover 140,000 new premises and to deploy on at least 500 new masts.
- 4.63 We believe that the benefits provided by these combined proposals may be broadly equivalent to those that would have been delivered by our previous proposals, where an operator could have delivered a 92% coverage level anywhere, and in any way it chose.
- 4.64 This is because our revised proposals would ensure coverage is provided in places where people live and travel around, with new infrastructure delivering a step-change in coverage for the people benefitting in these areas. Including a more onerous obligation in the award could make it less likely an operator would take this commitment on, meaning no coverage benefits would be delivered.

The case for imposing coverage obligations

- 4.65 As set out above, to support a proportionate outcome, we have undertaken a further assessment of the costs of meeting our proposed obligations – including by gathering further information from the MNOs under our formal powers. We have also carried out further analysis of the benefits that we believe would be associated with increased coverage.
- 4.66 Below, we set out the main aspects of our current approach for assessing the social benefits of improved mobile coverage, which is discussed in more detail in annex 11. We recognise that there is inherent uncertainty in assessing the social benefits from increased mobile coverage. Therefore, our analysis necessarily involves a degree of regulatory judgment, exercised in light of our duties.

The counterfactual for assessing the benefits of improved coverage

- 4.67 The social benefits of the coverage obligations are the benefits to citizens and consumers which we expect should result from the improved coverage achieved by the obligations. To assess these benefits, we must take a view on what the coverage situation would be with and without the coverage obligations, over an appropriate period of time.
- 4.68 Any coverage obligations we impose as a result of the award would remain in effect for the duration of the awarded licences (i.e. at least 20 years). Therefore, in assessing the benefits

of the obligations, we consider it appropriate to look at a period of 20 years into the future.⁴⁷ We therefore need to take a view on operators' expected coverage over this period of 20 years, while recognising that the benefits from the obligations will be larger if operators would otherwise only increase coverage later on in this period (noting that we are proposing that the coverage required by the obligations would need to be met within four years of the auction).⁴⁸

- 4.69 This assessment of social benefits is inherently a forward-looking judgment over a long period of time, with associated uncertainties, and limitations in available evidence. These apply both to the nature and scale of benefits to citizens and consumers with the coverage obligations, and to what operators would do over the 20-year period without these obligations.
- 4.70 A starting point to consider the situation *without* the coverage obligations is a high-level estimate of the level of coverage that the operators expect to provide by the time of the award.
- 4.71 Based on data we have gathered from the operators since the March 2018 consultation, we expect, as a starting point, operators' level of good 4G outdoor mobile coverage could range from approximately [X REDACTED] of UK landmass at the time of the award. We are, however, interested in how these coverage levels might change over the 20-year period.
- 4.72 Taking a step back, over that period, we think it is reasonable to expect all operators to reach broadly similar geographic coverage levels in the absence of coverage obligations, despite the current differences between them.
- 4.73 Operators will make their own commercial decisions and some might prioritise greater geographic coverage levels than others. However, they all compete in the same market and, over this period of time, some important aspects of the current arrangements affecting the differences in near term coverage levels, such as the Emergency Service Network (ESN) contract between BT/EE and the Home Office (which is discussed in more detail below), may unwind or potentially be replaced by alternative arrangements.
- 4.74 Whilst some differences in coverage levels between operators might remain, we consider it is reasonable to expect these to be relatively limited over 20 years. More specifically, in the absence of intervention, we expect there will be some continued targeted coverage roll-out from operators, though we expect the extent of this to be fairly modest in terms of geographic coverage, at least in the near term.

⁴⁷ While the licences and coverage obligations would be indefinite, we consider the 20-year initial term of the licences to be the relevant time period for the assessment of the social benefits. This is because we want to put the social benefits on the same basis as operators' bids, which will reflect the costs of meeting the obligations. We anticipate that bids will relate primarily to the initial term of the licences, rather than the period beyond that. This is partly because annual licence fees may be applicable beyond the initial term and because the licence holders will have more certainty over the initial period, as the licences restrict our power to revoke them for spectrum management reasons during the initial term.

⁴⁸ We also note that the costs of meeting the obligations would be higher if operators would otherwise only increase coverage later on in this period. However, we consider that this cost would be modest.

- 4.75 It seems likely that operators who currently have lower coverage compared to rivals may achieve a larger increase than the operator with the most extensive good quality geographic coverage today (namely BT/EE). This could be because of competitive forces, and because (as our modelling shows) expanding geographic coverage is materially easier and more likely to be commercially profitable at lower levels of coverage.
- 4.76 Additionally, after the expiry of the current Emergency Service Network arrangements, we understand that all operators could have the opportunity to access the [REDACTED] ESN sites which will transfer back to the Home Office.
- 4.77 One of the operators with coverage levels below 80% today has already indicated to us that it expects to provide close to 82% coverage by the time of the auction. We therefore think it reasonable to consider that operators other than BT/EE will reach at least around 82% over the 20-year period we are considering.
- 4.78 BT/EE is expected to have the highest coverage at the time of the auction, partly because of the ESN contract. BT/EE predicts that around [REDACTED] of its geographical coverage will be delivered by infrastructure that supports its provision of the ESN contract.
- 4.79 However, there is no certainty that BT/EE will continue to offer a commercial service from all of these ESN sites, which tend to be in low footfall areas, after its contract for ESN provision has expired,⁴⁹ given that the costs of operating these sites could be higher than the revenue gain from continuing to operate them. It is therefore possible that BT/EE's coverage may fall in the future in the counterfactual. In light of these uncertainties, we consider it reasonable to assume that BT/EE's geographic coverage might reduce over the 20-year period that we are considering.
- 4.80 Although we acknowledge the uncertainty which is inherent in making any predictions about the future, our view is that it is reasonable to assume that other operators will have approximately 82% coverage, and BT/EE will have approximately 84% coverage in this counterfactual.
- 4.81 We acknowledge that there is therefore a difference in the expected coverage operators are ultimately likely to provide. However, our view is that this difference will not lead to a substantial difference in the benefits each operator would provide if they win one of our proposed coverage obligations.
- 4.82 This is because our 'premises requirement' proposal should ensure that coverage is provided where it is most likely to be useful in a broadly equivalent way (i.e. in the areas where people live and businesses are located), whilst our 'new sites requirement' would safeguard the wider benefits we expect from the deployment of a minimum number of new sites. For simplicity, when we talk about operators' coverage in the counterfactual in the remainder of this sub-section, we refer to 82% coverage.

⁴⁹ We recognise that BT/EE may win the contract again once it expires (however, this is not certain). Our understanding is that this contract is due to expire in 2023 <https://www.contractsfinder.service.gov.uk/Notice/e86a8118-26e8-4a31-b8d9-3462666d656f>

The total and incremental social benefits associated with 90% good quality geographic coverage

- 4.83 To satisfy ourselves that this level of coverage is an appropriate level to include in the auction, we have considered both the total benefits and incremental benefits of the increased coverage:
- **Total benefits (from 82% to 90% geographic coverage)** – we have considered whether the total benefits of moving from 82% (our counterfactual) to 90% are at least as large as the underlying costs, which we estimate are within the range of £200-400m⁵⁰, as discussed below. This is to help us consider whether the costs of meeting a coverage obligation set at this level could be said to be too expensive relative to the expected social benefits; and
 - **Incremental benefits (from 88% to 90% geographic coverage)** – we have also considered whether the incremental benefits of moving from 88% to 90% are at least as large as the underlying incremental costs, which we estimate are within the range of £85-110m (in a conservative scenario where the obligation was delivered solely with new sites).^{51 52} This is to help us consider whether a coverage obligation at 90% would be likely to add net social benefits above a coverage obligation at 88%.⁵³
- 4.84 We expect there to be a declining incremental benefit, and an increasing incremental cost, as geographic coverage is increased. The declining incremental benefit reflects the fact that some parts of the UK landmass are very sparsely populated and attract few visitors. It is inherently difficult to predict the exact amount by which the incremental benefits of coverage decrease as the level of coverage increases.
- 4.85 To guide the comparison of costs and benefits, we consider it reasonable to assume a 5% decline in the incremental social benefits for each additional percentage point of landmass covered after 82%. We set out our reasoning for this in annex 12.
- 4.86 Our cost estimate for the increment from 88% to 90% is around £85m to £110m. On the basis that benefits decline by 5% for every additional percentage of coverage added, the total benefits of increasing coverage from 82% to 90% would be likely to need to be at least £400m-£500m for the incremental benefits to be large enough. Our analysis, which is mainly a qualitative assessment, suggests that this level of total benefits is reasonable. Therefore, we are proposing coverage obligations that are set at 90% of the UK landmass. In reaching this provisional view, we have assessed a wide range of relevant information, including:
- **The nature of the improved coverage:** We have estimated what the proposed obligations would deliver in terms of additional roads and premises benefitting from

⁵⁰ This is rounded from our range of £198m - £395m, which we present in annex 14.

⁵¹ This is rounded from our range of £85m - £107m, which we present in annex 12.

⁵² Note that we have not been able to carry out a detailed assessment of the increment between 89% and 90%, because we are here making assumptions around the kind of roll-out that an operator might undertake, and we think at this level of specificity there is a risk of spurious accuracy.

⁵³ This is because if the costs of increasing coverage for the final increment (i.e. from 88% to 90%) are higher than the expected benefits of that additional 2% of coverage, it might be argued that an obligation set at 88% would be more proportionate.

improved coverage. There are benefits both to those who live in the areas that experience the coverage improvement and to others who visit those areas.

- **Private use value:** Evidence suggests there is considerable value to users of mobile services from improved coverage. Operators may have insufficient incentives to provide such additional coverage because they are unable to capture all of this willingness to pay from consumers. This is consistent with evidence on the harm consumers suffer in areas of poor coverage. The social benefits considered in the context of this auction should include the private value benefits to consumers in excess of the price they pay.
- **Private external value:** In addition to the private use value, there may be other benefits from improved mobile coverage. For example, increased mobile coverage in an area might have indirect benefits for new and existing businesses because they are better able to make consumers aware of the services they are offering in rural areas.
- **Macroeconomic benefits:** As a result of the private use value and private external value, greater coverage of good 4G services is expected to lead to an increase in GDP, which will provide benefits to society. Some studies imply this could be a large effect, but it is difficult to draw firm conclusions about exactly how large this effect might be from the increased coverage from the obligations we propose.
- **Broader social value:** Citizens derive benefits from the contribution of better mobile services that are enjoyed by most or all people in society, typically irrespective of income. Greater mobile coverage creates broader social value through, amongst other things, providing health and safety assurances, increasing community cohesion, reducing the Digital Divide and improving the provision of social goods such as healthcare and education.

4.87 There are difficulties in producing a robust quantified estimate of the benefits of 90% geographic coverage. However, having reached our provisional view, we have also undertaken high-level quantitative sense checks. These are set out at annex 12.

The total and incremental social benefits associated with 92% good quality geographic coverage

4.88 We have followed the same methodology as above to compare the total and incremental benefits and costs of moving from the counterfactual level of good quality coverage of 82% to 92% - the level that we initially proposed in our March 2018 consultation.

4.89 Our estimate of the incremental costs of moving from 90% to 92% good quality coverage is approximately £110m-£140m⁵⁴, based on the conservative assumption that the full coverage increase from 90% is delivered with new sites.

4.90 Our analysis suggests that the total benefits of increasing coverage from 82% to 92% would likely need to be within the £670m-£860m range for the incremental benefit of moving from 90% to 92% to match our estimate of the underlying incremental cost.

⁵⁴ This is rounded from our range £108m - £139m, which we present in annex 12.

- 4.91 Based on our analysis, which includes modelling of the number of premises and length of roads that would be covered in the step from 90% to 92%, we consider it unlikely that the benefits associated with increasing coverage from 82% to 92% would be at least as large as £670-£860m. Therefore, we do not consider that it would be proportionate to seek to award an obligation that required an operator to reach 92% good quality geographic coverage.
- 4.92 Our premises and new sites requirements mean that it is plausible that benefits provided by 90% geographic coverage are not significantly lower than an obligation that required 92% geographic coverage in any way or area they chose, because of the guarantee that coverage will be provided in beneficial areas, where people live, work or visit.
- 4.93 In the table below, we summarise our current estimates of the benefits and underlying costs of increased coverage, as derived from the analysis set out in annexes 12 and 14.

Figure 4.3: Summary table of our costs and benefits estimates

	March 2018 proposals 92% coverage	Revised proposals 90% coverage plus the additional requirements
Incremental costs of final two percentage points of coverage	£110m-£140m from 90%	£85m-£110m from 88%
Total costs of increasing coverage from 82%	£305-535m	£200-400m
Total benefits of increasing coverage from 82%	Need to be at least as large as £670m-£860m. We consider it unlikely that benefits would be as large	Need to be at least as large as £400m-£500m. We consider benefits are likely to need to be at least as large

Benefits of a second geographic obligation

- 4.94 In the March 2018 consultation, we proposed to include two geographic coverage obligations in the award (both set at 92%).
- 4.95 Some respondents questioned the case for a second geographic coverage obligation. BT/EE, in particular, argued that a single operator extending its coverage out towards 92% should be sufficient to deliver the full benefits of coverage to the people in those areas. BT/EE argued that the incremental benefit of a second provider in terms of additional consumer choice was low, particularly because prices would remain set on a national level.
- 4.96 Having considered BT/EE's comments, we remain of the view that two geographic obligations would deliver significantly more benefits than a single obligation, by delivering

benefits to a larger pool of consumers, because the customers of the second obligated operator would also benefit.

- 4.97 We believe there would be relatively limited switching as a result of the coverage obligations. This is because, whilst we expect there to be some direct benefits to people living in areas where coverage is improved, much of the benefit will accrue to people who travel through and visit these areas, either from neighbouring communities, or from further afield. We set this out in more detail in annex 11. We therefore consider that a similar number of customers would benefit from the second geographic obligation (i.e. the customers of the second obligated operator, who would also experience the benefits of improved coverage) as from the first.
- 4.98 We note that, in making this assessment, we have taken a simplifying assumption that each obligation is delivered by an operator with an ‘average’ customer base and that in practice there could be scenarios in which bigger and smaller shares of consumers benefited. We therefore consider that the benefits of a second geographic obligation would be broadly similar to the first.

The costs of providing coverage

- 4.99 We are now proposing an auction design that would enable bidders, based on their own assessment of costs, to decide which, if any, obligations to bid for.
- 4.100 However, we still need to take a view of how the costs of meeting our proposed obligations compare to the benefits we expect them to deliver. This provides us with an indication that these are levels the operators could reasonably be expected to bid for (given the maximum discount we propose).
- 4.101 BT/EE, O2 and Vodafone said that our initial proposals might underestimate the costs of meeting the coverage obligations and that this could result in the obligations going unallocated. [REDACTED].
- 4.102 We have therefore undertaken further work to inform our view of what it would take to deliver geographic coverage at 90%, with a ‘premises requirement’ of 140,000 premises (and to inform our ‘new site requirement’ proposals). Below, we set out the main aspects of our revised analysis for assessing the costs of improving coverage, which is discussed in more detail in annex 14.

High-level estimate of the costs of delivering geographic coverage

Our information gathering exercise

- 4.103 In order to estimate how much it is likely to cost operators to fulfil the proposed obligations, we had to first reach a preliminary view on the level of coverage each operator is likely to provide at the date of the auction. To do this, we used our formal powers⁵⁵ to request information from each of the operators about the levels of coverage they expect to provide by June 2019. This evidence only represents the starting point as we are

⁵⁵ Our powers under s32A of the Wireless Telegraphy Act 2006.

interested in how these coverage levels – and underlying costs - might change over the next 20-year period.

- 4.104 We have also gathered further information to inform our estimate of the number of new sites that a typical operator would need to build to increase its coverage from an appropriate ‘baseline’ to the 90% good quality 4G coverage level that we are proposing (and the higher level of 92% that we initially proposed).
- 4.105 The level of coverage provided by any new base station depends, among other things, on the terrain on which the base station is built. This is because the site location impacts the way in which airwaves travel (i.e. propagation) and therefore the level of coverage provided by the site. We have therefore used a propagation model agreed by the International Telecommunication Union (ITU) and commonly used network dimensioning software⁵⁶ to estimate where operators might choose to build new masts, and how many new masts would be required if they were built in relatively effective areas.
- 4.106 In undertaking this exercise we have been relatively conservative in the modelling assumptions that we have used. This is to reflect the fact that there may be significant deviations in predicted costs and real costs of deployments (for instance because some predicted site locations are unsuitable). Our conservative approach also reflects the asymmetry of risks between over-estimating and under-estimating costs: if we were to significantly under-estimate costs this could result in the coverage obligations failing to sell in the award process.
- 4.107 As part of our sensitivity analysis, we have also modelled results that a typical operator might achieve in less effective areas for coverage, with a 10-20% reduction in the coverage achieved per site.
- 4.108 We then used data about operators’ existing sites that we obtained under our formal powers in order to sense-check the results of this modelling exercise. We also checked that our approach was consistent with our proposed ‘new site requirement’ and ‘premises requirement’. We did this by analysing how other operators had already been able to provide coverage in places where each individual operator had a significant number of premises to which they do not provide outdoor coverage.
- 4.109 Finally, we assessed the approximate cost of building the new sites that we estimated would be required to reach 90% and 92% coverage. Again, we have based our cost estimates on data we received from each of the operators (using our formal powers) about the costs they incurred for new sites built in rural areas over the last 4 years.

Our current view based on the MNOs’ data

- 4.110 Below, we summarise our current view, based on the above data and methodology:
- **Baseline level** - Based on the MNOs’ data, we expect operators’ good quality 4G geographic mobile coverage could range from approximately [REDACTED] at the time of the auction. As we said above, our view is that it is reasonable to assume a

⁵⁶ Available from ATDI.

counterfactual of approximately 82% coverage in the absence of coverage obligations over the 20-year period that we are considering.

- **Sites required to increase coverage** - Were an operator to seek to meet a 90% geographic obligation solely by building new sites⁵⁷, we think the number of sites required for a typical operator could be between 500 and 1000 (which is higher than the 500-700 range we estimated in the March 2018 consultation for increasing geographic coverage to at least 89-90%). The lead operator may need to deploy fewer sites to deliver the geographic target (absent our ‘premises requirement’ and ‘new site requirement’). On this basis, we consider that a ‘new sites requirement’ of 500 new sites is likely to be appropriate to ensure the benefits the obligation delivers are in line with our expectations.
- **Costs required to build new sites** – We have estimated the costs based on operators’ data on the costs of recently built sites which we consider representative of the sites that would need to be built in order to meet the obligation. This suggests that the average cost per site is likely to be around £395,000 over a 20-year period.⁵⁸
- **Overall costs of increasing coverage** – In light of the above, we consider that a typical operator with around 82% coverage could increase its geographic coverage to 90%⁵⁹ by deploying new sites for approximately £200-400m. Our revised analysis suggests that the incremental cost of increasing coverage from 90% to 92% (which is the level of coverage that we initially proposed) is £110m-£140m.

Extended Area Service Sites

- 4.111 In our March 2018 consultation, we said that a number of factors are likely to allow the operators to deliver at least a further 2-3% of geographic coverage on top of 89-90% within the indicative £300m envelope that we initially estimated, with a significant factor being the potential availability of the EAS sites that the Home Office is building.
- 4.112 Operators including BT/EE, Vodafone and O2 highlighted concerns about the assumption we had initially made in relation to these sites. They said that there is uncertainty around when and how these sites will be made available, as well as their location.
- 4.113 We recognise that there is still significant uncertainty about how and when the EAS will be made available to operators. Therefore, in estimating the costs of reaching the level of geographic coverage that we are proposing (i.e. 90%), we have not factored in potential cost savings that operators might derive from use of these sites.
- 4.114 In line with this approach, we provisionally consider that if these sites were built and made available to all operators before the deadline for compliance with the proposed

⁵⁷ We note that [REDACTED] said in their responses that they expect to be able to add some coverage from existing sites and that this assumption is therefore conservative.

⁵⁸ Note that this cost, and the subsequent range of £200-£400m reflects our view of costs based on a social time preference rate of 5.6% which is comparable to the approach we have used for assessing benefits. We think the appropriate discount rate for operators is likely to be based on a nominal weighted average cost of capital rate of 7.6% (see annex 14).

⁵⁹ From a starting point of approximately 82% geographic coverage.

obligations, it would be consistent not to include the coverage provided by these sites within our assessment of compliance with the 90% coverage obligations that we are proposing.

- 4.115 In this scenario, an operator acquiring a coverage obligation and accessing the EAS sites would in practice deliver substantially higher coverage than 90%.

Cost reduction factors

- 4.116 We have also considered further the weight we can place on other factors that could reduce operators' costs. These factors include:
- ongoing commercial roll-out, beyond the relatively targeted increases we are now accounting for in our longer run assessment of where coverage may reach absent an obligation;
 - the potential availability of new sites from the Scottish Government's 4G infill programme; and
 - the ability of operators to deliver coverage improvements for lower investment levels using existing infrastructure (either physical adjustments to an operator's own masts, technical adjustments to their operation, or deploying on existing masts owned by another operator or third-party infrastructure provider).
- 4.117 We have not relied on, or sought to quantify, these potential factors, since their commercial viability is uncertain. Taken in the round, these factors suggest that delivering 90% coverage is likely to be feasible at lower costs than we have estimated (although no one of these individual factors can be completely relied on to deliver coverage at a lower cost).
- 4.118 However, if we were to propose higher thresholds, we think this might result in the coverage obligation failing to sell. For this reason, we think it is appropriate to err on the side of caution when considering the effect of these more speculative factors.
- 4.119 There is also a risk that, were measures to improve coverage from existing sites to be adopted as the main aspect of an operator's coverage strategy, they would not deliver the full set of benefits we are seeking when offering a £300-400m discount. Our proposal for an additional requirement that an operator must deploy at least 500 new sites to meet the obligation, as well as delivering better quality coverage, acts as a safeguard against this, whilst remaining at the conservative end of our estimated cost envelope.

Cost differentials within the mobile industry

- 4.120 Currently, the mobile operators have different levels of good geographic 4G coverage. Based on the information that we have gathered from them using our formal powers, we expect that the operator with the greatest good mobile coverage could be delivering [X REDACTED] geographic coverage at the time of the auction, while the lowest coverage capability amongst the operators could be around [X REDACTED].
- 4.121 In responding to our consultation, Vodafone argued that, whilst it considered it inappropriate to reward poor historic performance in relation to coverage with lower or

more favourable targets for these companies, it was equally inappropriate not to consider the advantage of BT/EE in terms of geographic coverage, particularly as a result of the ESN contract with the Home Office.

4.122 We acknowledge that operators will have different levels of coverage at the time of the auction, and therefore different costs of meeting the obligation. Those differences in levels of geographic coverage partially result from past commercial/investment decisions operators have taken to invest in coverage and/or decisions to bid for the ESN contract. As a matter of policy, we do not want to take an approach which risks unduly rewarding operators who have to date chosen not to prioritise investment in geographic coverage, against those that have.

4.123 However, we think the extent of any cost differential should be limited, for the following reasons:

- As we said above, we consider that it would be reasonable to assume that geographic coverage will converge over the 20-year period that we are considering.
- We understand that a significant portion of sites which have been built to fulfil BT/EE's commitments under the ESN contract will be transferred back to the Home Office on expiry of the ESN contract. We understand that the Home Office intends to give all operators the opportunity to access these sites in the future (and we understand that many of these sites have been built for multi-occupancy for this reason). Our provisional view is that it is reasonable to assume that the other operators may be able to more cost effectively increase their coverage to some extent by utilising these sites, than through building their own new sites.
- As explained above, our proposed coverage obligations include a 'premises requirement' to provide additional good quality outdoor coverage to at least 140,000 premises which it does not currently serve, in order to ensure that the coverage is delivered in areas where it is most useful. In practice, this is likely to require the lead operator to deploy more sites to deliver the 90% level than it would have to without this constraint. We also consider it likely that this requirement will be proportionately harder to meet for operators who start with more extensive coverage, since they will be required to cover more premises per percentage point of landmass they add to their coverage.
- Our proposed coverage obligations also include a 'new sites requirement' requiring the winning bidder to build at least 500 new masts in meeting the obligation. We have included the new sites requirement in our proposals in order to ensure that the obligation delivers the benefits we expect. However, the new sites requirement is also likely to contribute to equalising operators' costs of meeting the obligation. This is because, based on operators' predicted coverage levels, we expect that [REDACTED].
- An operator with lower initial coverage levels would be able to deploy in more areas where another operator has already found it commercially viable to cover, even without the obligation.

4.124 We therefore consider that our coverage proposals appropriately take account of the different starting points for each operator.

Coverage requirements in the UK Nations

4.125 In the March 2018 consultation, we noted that we wanted to ensure that all the UK Nations could benefit from the coverage obligations. Coverage levels currently vary substantially across the UK, with our analysis suggesting that the density of population in an area is the key determinant for whether good coverage is provided.⁶⁰ The impact of this for geographic coverage across the UK Nations is set out in Figure 4.4 below, which shows the range of coverage achieved by different operators in different UK Nations. (Note that the lead and lagging operator is also different in different nations).

Figure 4.4: Good quality 4G coverage from individual operators in UK Nations⁶¹

	Geographic Coverage	Outdoor Premises Coverage	Indoor Premises Coverage
England	88-94%	99%	89-95%
Northern Ireland	86-94%	94-99%	67-93%
Scotland	51-68%	97-99%	87-94%
Wales	67-83%	96-98%	87-89%

4.126 We said in our March 2018 consultation that there was a risk that, without specific thresholds for each UK Nation, the bulk of new coverage could be directed towards England. In order to mitigate this risk, we proposed setting the following minimum coverage thresholds for our obligations in each of the UK Nations:

- for the geographic coverage obligations, which we initially proposed to set at 92% of the UK, we proposed nations requirements of 92% in England and Northern Ireland, 83% in Wales and 76% in Scotland;
- for the premises obligation, which would require the successful bidder to deliver good quality in-building coverage to 60% of unserved premises, we proposed a uniform threshold of 60% for each UK Nation (we discuss our assessment of this proposal in annex 17).

⁶⁰ Economic Geography, Ofcom, 2017 https://www.ofcom.org.uk/__data/assets/pdf_file/0031/108778/economic-geography-2017.pdf

⁶¹ Based on data provided by operators in September 2018, rounded to the nearest percentage point and with an offset of 10dB applied to estimate indoor coverage levels

- 4.127 Our approach was based on the principle that we should seek to deliver coverage increases for each UK Nation that reduced the unserved landmass by an equivalent proportion up to the level of the UK obligation, thereby ensuring the largest improvements for those nations with the worst coverage today.
- 4.128 Many stakeholders welcomed our proposals to ensure that the benefits of the coverage obligations were fairly distributed between the UK's Nations.⁶² However, some stakeholders, including the Welsh and Scottish Governments, indicated that they would welcome more evidence on how we had calibrated these requirements for the geographic obligations and suggested that our proposed thresholds for coverage in each of the nations might not go far enough.⁶³ Their suggestions included seeking to level out the coverage of the lagging UK Nations with those with the best coverage today.
- 4.129 In light of consultation responses, we have considered whether it would be appropriate for coverage obligations to require coverage in Scotland and Wales up to the levels that are being reached in England and Northern Ireland.
- 4.130 However, our high-level modelling exercise suggests that this would likely require operators to deploy several hundred more masts in these locations than we have currently forecast (see our analysis in annex 14). This indicates that providing this coverage in Scotland alone could require at least 700-800 new sites, many of which would be in very remote areas, with costs likely to be at least as high as our overall obligation proposals in the round.
- 4.131 Such an approach would significantly raise the overall cost of the coverage obligations to operators, increasing the risk that the coverage obligations go unsold. In addition, in our view, such an approach would not raise the social benefits that would be delivered by a commensurate amount, since expanding coverage in Scotland and Wales is much more challenging given the physical geography and the distribution of population settlements.
- 4.132 Such an approach could also lead to very limited investment in England and Northern Ireland. Consequently, we remain of the view that requiring operators to deliver the same level of geographic coverage in all of the UK Nations would not be proportionate.
- 4.133 We therefore propose to maintain our principle that each UK Nation should receive coverage uplifts that reduces the unserved landmass an equivalent proportion, up to the level reached of the UK obligation. However, since our March proposals, there have been two significant changes in the factual context for our assessment:
- we have revised our view of the overall coverage level that is likely to be proportionate for the UK as a whole down from 92% to 90%; and

⁶² In particular, BT/EE viewed the specific thresholds for the nation as appropriate to reflect the different terrain and population densities of each nation. Three (paragraph 2.2) said that "Ofcom may wish to [also] include binding sub-targets for each of the four nations to ensure expansions in coverage are delivered more evenly across the UK". Shropshire Council and North Yorkshire County Council also agreed with our proposed approach.

⁶³ The Ofcom Advisory Committee for Wales (ACW) and the NFU suggested that the requirements for Wales should be higher. The CLA argued that the targets for Wales and Scotland were "insufficient and would reinforce and entrench economic divide between the nations".

- we have received new information from operators on the coverage levels they expect to reach at the time of auction with coverage levels in Scotland further away from our original target.

4.134 Applying the same principles as in our March consultation, and maintaining our preference for safeguarding the largest increases for those with the worst coverage today, we have therefore revised our proposals as follows:

Figure 4.5: Revised proposals for coverage requirements in the Nations⁶⁴

	March proposals for Nations requirements	March baseline for average operator coverage in 2019	New baseline for average operator coverage in 2019	Revised proposals for Nations requirements
Scotland	76%	64%	62%	74%
Wales	83%	75%	76%	83%
Northern Ireland	92%	87%	90%	90%
England	92%	91%	90%	90%

4.135 Our proposed targets for Northern Ireland and England have both therefore fallen back from the levels we consulted on in March, but continue to safeguard that the operator holding the obligation would deliver at least the same level of coverage in these nations as for the UK overall.⁶⁵ We note that these targets would continue to require some further roll-out for some operators, and that our requirement to cover unserved premises is also likely to see ongoing investment in England and Northern Ireland as a result of our proposals.

4.136 Our proposal for Scotland represents the most significant coverage increase for any UK Nation, based on the average starting point of operators, with that increase remaining in line with our March 2018 proposals (i.e. a 12ppt uplift). However, the lower starting point operators have told us that they expect to achieve means that pushing coverage further would be very expensive.

4.137 We also expect a very significant portion of new mobile sites built under our obligation would be provided in Scotland, and that as a result coverage in inhabited areas would be near UK levels. Requiring more coverage beyond this level would add significant cost

⁶⁴ June 2019 baseline predictions are derived from an average of all 4 operator's coverage predictions provided to Ofcom.

⁶⁵ Note that coverage in England from an average operator is likely to be already above the levels of the UK obligation (and therefore our proposed safeguard). We consider that operators will continue to be incentivised to improve coverage in rural England because of our premises requirement.

(which could risk the obligation going unsold) and increasingly be providing coverage in remote areas where the benefits might not be proportionate.⁶⁶

- 4.138 Operators expected starting points in Wales have stayed largely in line with our March estimates, allowing us to maintain the same overall target here.

Timescales for delivery

- 4.139 In the March 2018 consultation, we proposed that all the coverage obligations should be met within three years of the award. Our objective remains to balance the level of commercial challenge in delivering new coverage – including getting planning permission for and deploying new mast sites in more remote locations – and the benefits to consumers of realising this new coverage in a timely way.
- 4.140 Consultation responses reflected the importance of this challenge, with a number of stakeholders noting that it was important that coverage improves as soon as possible.
- 4.141 The Scottish Government and the Welsh Government considered that there was a risk that new coverage would be delivered only towards the end of the delivery window, and that 2022 was too late for many consumers to benefit.
- 4.142 The LGA noted that it did not recognise the planning system as a major constraint, and that a two-year delivery window could be appropriate. The Federation of Small Businesses suggested that interim requirements as early as 2019 or 2020 could be appropriate, while the Country Land and Business Association considered our overall process could be accelerated to bring forward coverage improvements.
- 4.143 Conversely, some MNOs argued that this timetable was too aggressive and did not reflect practical experience of deployment challenges. BT/EE argued that a five-year window would be more appropriate and feasible, although it would still be challenging to deliver, citing their experience of deploying new sites in remote areas for the ESN programme.
- 4.144 Vodafone suggested that a [REDACTED] window would be appropriate.⁶⁷ Both Vodafone and BT/EE noted that there was a potential risk that a limited supply of appropriate skills could slow deployment rates. O2 also considered that more time was needed and said that reforms of the planning system that might support faster deployment were a work in progress.
- 4.145 We consider that the evidence on the achievability of a three-year deadline is mixed. For example, whilst the ESN programme has involved many challenges, a substantial number

⁶⁶ We note that our proposals will see very significant coverage across the 70% of Scotland which is defined as ‘remote rural’ by the Scottish Government. It is less likely to bring coverage to the 19% of Scotland defined as ‘wild’ by Scottish Natural Heritage.

⁶⁷ In particular, in its response to the March 2018 consultation (paragraphs 3.1-3.8), EE said that its experience of delivering [REDACTED] ESN sites supported its view and confirmed some of the challenges involved, including access to land through a limited pool of landholders, overcoming local objections and the need to ensure line of sight for backhaul.

of new sites have gone from initial planning to being built and on air within around three to four years. We have also been presented with evidence from operators that, typically, for a rural site they would plan for around an 18-24 months delivery cycle.⁶⁸

- 4.146 Experience from the Mobile Infrastructure Programme was that those sites that were delivered required a ‘planning to build’ cycle of not more than three years, and in many cases much less.⁶⁹ This suggests that in principle, rural sites can be delivered from scratch in less than three years. In practice, however, the Mobile Infrastructure Programme delivered fewer than 100 sites, with some instances where identifying suitable site locations took more time than was available.
- 4.147 As explained above, since our March 2018 proposals, we have increased our estimates of the total number of sites required to deliver the proposed obligations. The timeframe required to deliver a larger programme of around 500-1000 new sites could be significantly longer than the time required to deliver a single site. As the number of sites increases, complication and risk are likely to increase for operators. In particular, we acknowledge that the top end of our estimated range for the number of sites required to deliver the obligation has increased, and this could mean scenarios in which a greater number of complex sites than we had previously envisaged would be needed.
- 4.148 We therefore consider that a three-year deadline for meeting a 90% level for geographic coverage might introduce material risks that deter operators from bidding for a coverage obligation, because the evidence we have gathered indicates that for a small number of sites, delivery in this timescale could be challenging. However, we do not think that the evidence that has been presented would justify a much longer delivery window for this level of coverage. We are therefore proposing to extend the time allowed to deliver the obligation to four years. We anticipate that to meet this deadline, operators are likely to deploy a significant number of sites well before this, and that consumers should therefore benefit from some coverage improvements beforehand.

Measuring compliance with the coverage obligations

Minimum level of service for good mobile coverage

- 4.149 In our March 2018 consultation, we stated that we would use the approach to measuring coverage that we introduced in our Connected Nations 2017 report. This new approach

⁶⁸ BT/EE indicated it could take a 12-18 month period in total to deploy and activate a single rural site; Vodafone said that they had planned a [REDACTED] for their “Grow the Grid” sites, but that in practice this had been optimistic in many cases.

⁶⁹ The Mobile Infrastructure Programme was a £150m Government funded project to deliver new mobile infrastructure in total not-spots. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/73071/Mobile_Infrastucture_engagement_Rel_1_0.pdf Arqiva was contracted in 2013, with a re-planning exercise undertaken in 2014 to confirm the location of not-spots. We consider this would be a reasonably equivalent point in the planning cycle for an operator building out new coverage.

requires a level of quality that provides consumers with the kind of experience they expect today, with reliable voice calls and a high probability of access to at least 2 Mbps.⁷⁰

- 4.150 We said that, in practice, this level of service implies that a mobile operator is required to deliver a 4G signal strength of -105 dBm to achieve outdoor geographic mobile coverage in any given 100m² pixel of the UK's landmass. For the premises obligation, we proposed that a signal at least 10 dB higher than that needed to provide a good outdoor service is needed to ensure a good service indoors.
- 4.151 Some respondents argued that this could lead to disproportionate costs. BT/EE suggested that a good quality service could be delivered in rural areas at -115 dBm. While Vodafone recognised -105 dBm as a relevant benchmark for a good quality data service, they questioned the value of providing this level of coverage in remote areas. They argued that this could force operators to fill in small gaps within their existing network at disproportionate costs and suggested a lower quality of 1 Mbps would be appropriate in some areas.
- 4.152 We consider that our view of what consumers value as a good service remains appropriate: i.e. allowing nearly all voice calls which last for at least 90 seconds to be made and completed without interruption, and nearly all data connections to deliver a speed of at least 2 Mbps, with an average success rate of at least 95%.
- 4.153 Our research suggests that consumers value a reliable mobile service with a high call success rate. Consumers tend to value access to services that are likely to work well with a 2 Mbps connection. We understand that the mobile operators have also historically sought to ensure high levels of call success rates of 95% or better.⁷¹ We note that this approach ensures a minimum level of service at the edge of a cell, and that very often consumers will experience higher levels of service and faster speeds.
- 4.154 We remain of the view that our new measure of good mobile coverage (i.e. at least -105 dBm for outdoor coverage) is an appropriate benchmark that ensures a high probability (i.e. 95%) of a successful voice call and access to 2 Mbps data service. This view is informed by a range of measurement activity over recent years, including to support our annual Connected Nations report. We set this work out in more detail in annex 14.
- 4.155 We believe that it is appropriate that people in rural areas have the opportunity to enjoy a good level of service, along with consumers in the rest of the UK. The measurement activity that we have conducted in rural environments has demonstrated that the signal levels we have identified are likely to be appropriate for ensuring this. They are also likely to secure a degree of future-proofing, as trends in consumer behaviour are likely to see expectations around the quality of mobile data services continue to increase in the future.

⁷⁰ We define a high probability as more than a 95% probability for both voice and data services. See annex 14 for more detail.

⁷¹ Some stakeholders questioned whether 2 Mbps was a sufficiently ambitious target to provide good quality coverage. We note that, as set out in annex 14, this requirement is based on the minimum experience available to a user in the cell, and that better coverage will be available much of the time.

- 4.156 We also note that under our current proposals, operators will continue to have some choice between infilling areas with patchy coverage that fall below our required level (some of which will be larger and some smaller) and building out into areas which currently have no coverage.
- 4.157 In light of the above, our proposed approach to what constitutes good mobile coverage remains the same as set out in our March 2018 consultation.

Our approach to measuring compliance

- 4.158 In the March 2018 consultation, we said that we would set out for stakeholders the criteria and methodology that we propose to impose for assessing compliance. We said that we were anticipating that we would use a combination of our own assessment tools, including drive testing, and information provided by the operators.
- 4.159 We also said that we were not in principle opposed to allowing coverage contributions to be delivered through roaming agreements with other operators and that our key test would be whether this coverage was of a good quality. We now set out in more detail how we expect to measure compliance with these obligations.
- 4.160 It is important that, for any obligations placed in operators' licences as a result of this award, Ofcom has a clear, robust and consistent approach to check this has been delivered. This will support informed bidding for parties interested in acquiring the obligation, and ensure that good outcomes are delivered for consumers.
- 4.161 In 2013, we provided bidders for the 800 MHz award with a single model⁷² that would be used to measure compliance with the obligation, for this purpose. We believe that there is merit in taking a similar approach for this award.
- 4.162 However, we also recognise that operators have developed their own sophisticated processes for measuring the coverage that they provide today and we undertake testing to satisfy ourselves that their coverage predictions are reasonable.
- 4.163 Accordingly, we propose to provide operators with a single model for geographic coverage whose outputs we will calibrate to align with operators' own coverage baselines, but which will provide a single measure of the coverage increment they deliver under the obligation. If our model predicts that an operator's coverage today is lower than the operator's own predictions, we will adjust to reflect this (whilst measuring whether the incremental coverage we expect the operator to add is delivered).
- 4.164 This model will be based on network inputs operators will provide, and we will assure. We propose to require winning operators to provide us with their own predictions and data on their physical network immediately after the auction and at the time of compliance, which we will run through our model.

⁷² 4G Coverage Obligation Notice of Compliance Verification Methodology: LTE.
https://www.ofcom.org.uk/_data/assets/pdf_file/0026/58292/4gcov-verification.pdf

- 4.165 This will determine the baseline for our model, the delta with operators' own predictions and therefore the coverage requirement that must be met using our model. We intend to make this model available for operators to comment on during this consultation period.
- 4.166 We remain of the view that good quality coverage delivered through roaming should count towards delivering the obligation. For either an existing operator, or any new entrant acquiring the obligation, they will need to provide us with the same evidence for any and all networks they are using to deliver the required coverage (including for any parts of the obligation they deliver through roaming). They will also need to provide us with evidence of the extent of the availability of good service this provides to their customers.
- 4.167 We also intend to carry out our own assessment of the information the obligated operator provides to demonstrate it has complied with the premises obligation (including drive test campaigns in relevant locations) and checks to confirm that new infrastructure deployed to meet our 'new macro site' requirement has been delivered.
- 4.168 We envisage that this requirement will be met where operators can demonstrate that they have deployed on infrastructure that is new to them.⁷³ We will set out further details on our proposed approach through the consultation period.

Provisional conclusions

- 4.169 The coverage obligations that we are proposing to include in the auction are summarised in the table below.

Figure 4.6 – Summary of our revised proposals on coverage obligations

Our Proposed obligations	Requirements	Nations requirements	Deadline
Obligations in two licences with: i) a Geographic coverage requirement ii) a premises iii) a new site requirement	90% of the UK landmass; at least 500 new wide area coverage sites; at least 140,000 premises gaining at minimum outdoor coverage	90% for England 90% for NI 74% for Scotland 83% for Wales	4 years

⁷³ Given our provisional decision not to count the EAS sites towards these obligations, we would not envisage operators deploying on these sites as meeting the new site commitment (recognising that at least one operator may deploy on these sites in any event). We envisage that deployments on other publicly funded infrastructure, or existing infrastructure owned by other operators or third parties could count towards the requirement.

Consultation question

Question 1: Do you agree with our proposals on the coverage obligations as set out in this section? Please give reasons supported by evidence for your views.

5. Competition assessment

5.1 In this section we assess any potential competition concerns that might arise from the auction of 700 MHz and 3.6 GHz spectrum and propose measures to address them, where necessary.

Summary

5.2 As set out in section 2, one of our objectives in this auction is to ensure that consumers and businesses continue to benefit from strong competition in the provision of mobile services.

5.3 We first identify whether there are competition concerns that could arise from the auction and then, if there are, what the consequences might be if we did not adopt measures to address them. In conducting this assessment we consider, among other things, current spectrum holdings, the properties of the spectrum that we are awarding and various factors which affect competition in the UK mobile market.

5.4 To identify the most relevant potential concerns, we consider the likelihood that these concerns will materialise and the severity of their potential impacts. We then assess what measures, if any, may be proportionate and effective to address those relevant concerns.

5.5 The table below summarises our initial assessment.

Figure 5.1: Summary of concerns

Potential concern	Potential impact and severity	Likelihood in absence of measures	Overall relevant concern?	Proposed remedy
1. Less than four credible MNOs	Very significant concern if one or more MNOs ceased to be credible, e.g. through lack of route to 5G	Very unlikely	No	None
2. Risk that competition will weaken as a result of:				
a. Significant asymmetry in overall spectrum	Significant concern if an MNO ended up with a particularly large or small share	Fairly likely	Yes	Cap of 416 MHz (37%) of overall spectrum

Potential concern	Potential impact and severity	Likelihood in absence of measures	Overall relevant concern?	Proposed remedy
b. Significant asymmetry in 'capacity' spectrum	Significant concern if an MNO ended up with a particularly large or small share of 'capacity' spectrum	Similar risk to overall spectrum concern. Hard to meaningfully define 'capacity' spectrum, but unlikely to differ much from overall spectrum holdings	No	None beyond overall cap
c. Significant asymmetry in 'spectrum that can be used for 5G'	An MNO without a route to 5G would be very concerning – could even threaten credibility	Highly unlikely – all MNOs already have a route to 5G with current spectrum	No	None
d. Significant asymmetry in low frequency spectrum	Concern if asymmetry produces differences in coverage capabilities which harm competition	Asymmetry is likely to remain after the auction but we do not consider this would significantly harm competition	No	None

5.6 We have provisionally concluded that the most concerning relevant outcome is the risk of significant overall asymmetry of spectrum holdings, in particular if one MNO were to end up with a particularly large share of overall spectrum.

5.7 As a result of the 2.3 and 3.4 GHz award in April 2018, the previously large asymmetries in overall spectrum holdings have reduced. We propose to impose a 'safeguard cap' on overall spectrum to ensure that the 700 MHz and 3.6-3.8 GHz award does not reinstate a significant asymmetry in spectrum holdings. The cap would be set at 416 MHz of all relevant spectrum, which is equal to just over 37%.⁷⁴ This would restrict BT/EE to acquiring 120 MHz of the 200 MHz to be awarded; Vodafone could acquire 190 MHz and H3G 185 MHz. O2 would not be restricted by the proposed cap.

5.8 We have considered whether certain spectrum bands are particularly effective at providing capacity ('mid frequency' bands between 1800 MHz and 6 GHz), compared to other frequencies, and also whether there are asymmetries in 'downlink spectrum'. We have provisionally concluded that any concerns about asymmetries in mid-frequency or downlink spectrum are addressed by the proposed overall cap, since the overall cap is

⁷⁴ The reasoning behind choosing 416 MHz is discussed in detail below.

aimed at addressing potentially large asymmetries in capacity. We do not propose to impose any additional cap on any sub-set of spectrum bands that may be particularly suited for capacity.

- 5.9 Our concerns about the risks that very asymmetric holdings in either low frequency or 3.4-3.8 GHz spectrum after the auction would weaken competition are lower than our concern over asymmetry in overall spectrum. In our view, it is unlikely that any asymmetries in low frequency spectrum would result in a weakening of competition. We also consider that each MNO has a route to 5G with current spectrum holdings and therefore we are not particularly concerned about asymmetries that may arise in 3.4-3.8 GHz spectrum.
- 5.10 We consider that it would be very detrimental to competition if one or more MNOs were to cease to be credible. However, we expect that all MNOs will have the spectrum portfolios they need to remain credible even if they did not win any spectrum in this auction and, therefore, this is not a relevant concern in this auction.
- 5.11 We therefore do not consider that any other measures are necessary or proportionate to promote competition in the mobile market.
- 5.12 The assessment in this section mainly focuses on competition in national wholesale and retail mobile services because we expect the bands in the award to be primarily used to offer mobile services at a national level.
- 5.13 The mobile market today is worth around £15.6bn with the four national operators generating nearly all of that.⁷⁵ Given their importance to mobile services, our assessment is focused on the four MNOs and their spectrum holdings. However, we also welcome other types of competition and recognise that a new entrant may find innovative ways of using spectrum that benefit citizens and consumers. We discuss alternative uses for these bands in annex 5.

Context for our assessment

The current UK market for mobile

- 5.14 There are currently four national mobile network operators (MNOs) in the UK: BT/EE, Vodafone, O2 and H3G (Three). The four UK MNOs operate at different scales. H3G is the smallest with c. 12% share of wholesale subscribers, Vodafone has 22%, and O2 and BT/EE each have around a third of wholesale subscribers (33%).
- 5.15 There are two network sharing arrangements in operation in the UK – the MBNL agreement between H3G and BT/EE, and the Beacon or CTIL agreement between O2 and Vodafone. These agreements allow operators to share passive network elements (such as masts, cabinets, antennas and mobile backhaul connections) and/or active elements such as radio base station equipment.

⁷⁵ These are the estimated retail revenues generated by mobile telephony as reported by Ofcom, Telecoms Data Tables, https://www.ofcom.org.uk/_data/assets/pdf_file/0022/124636/q2-2018-telecoms-data-update.pdf

- 5.16 MNOs use their mobile networks to provide retail services under their brand. They also provide mobile network services (wholesale services) to a number of mobile virtual network operators (MVNOs). Some of these MVNOs are owned by the MNOs and some are independent. We have supported this structure through regulatory measures in the past as we believed that having at least four credible MNOs was important for consumers.⁷⁶
- 5.17 Having looked at competition in the UK mobile services sector today, we consider that the current provision of mobile services is functioning well, with competition between the four MNOs delivering good outcomes for consumers.
- 5.18 We still believe it is in consumers' interests for there to be at least four credible MNOs. The existence of four credible MNOs supports retail competition directly because MNOs are major competitors in supplying retail mobile services to consumers. It also supports retail competition indirectly because the MNOs compete to provide wholesale access to MVNOs. Independent MVNOs, in total, account for 10% of retail subscriptions.
- 5.19 It is important to retain at least four MNOs partly because barriers to entry are high. If the number of MNOs were to decrease from four to three, any resulting weakening of competition could be long lasting and difficult to reverse, as new entrants might face high barriers to entry even if competition was not working as well for consumers, such as through higher prices or less innovation.
- 5.20 Market concentration has decreased at the retail and wholesale level over recent years. Ofcom research⁷⁷ shows that there has generally been a downward trend in mobile prices since 2013. External research comparing mobile services across different countries has also shown the UK to have relatively low mobile prices compared to other countries.⁷⁸
- 5.21 At the same time, all MNOs have continued to invest in providing new services and significant improvements for consumers. For example, 4G/LTE coverage in the UK has continued to develop, reaching around 90% of indoor premises for all MNOs.⁷⁹ All the MNOs won spectrum in our 2018 auction, which is likely to enable them to offer a better mobile broadband experience to their customers and prepare to launch 5G services. Consumer satisfaction with UK mobile services remains high, despite small decreases in some satisfaction indicators (e.g. value for money).
- 5.22 The full details of our assessment of the UK mobile market are set out in annex 6 of this consultation.

⁷⁶ In our 4G auction in 2013, we reserved some of the available spectrum for an MNO other than the three largest MNOs to avoid consolidation down to three MNOs as a consequence of the auction. H3G obtained this reserved spectrum.

⁷⁷ [Pricing trends for communication services in the UK](#) and <https://www.ofcom.org.uk/research-and-data/multi-sector-research/general-communications/pricing>

⁷⁸ This is based on reports from the [European Commission](#) and [Telecompaper](#)

⁷⁹ This is indoor coverage and not geographic coverage. As discussed in other sections of this document, there is significant scope to improve geographic coverage in the UK.

Current allocations of spectrum

- 5.23 Existing spectrum shares, and how they might change as a result of this award, are at the core of our competition assessment. Figure 5.2 below presents the MNOs' current spectrum holdings. This includes all mobile spectrum, including the 3.4-3.8 GHz band, which we do not consider to be useable for mobile services until 2020, or possibly 2019. This is because of the current lack of devices for this band and some deployment restrictions in the 3.6-3.8 GHz band due to the presence of satellite earth stations and fixed links.^{80,81}
- 5.24 BT/EE has the most spectrum across all frequencies with 295 MHz; and O2 has the least (166.4 MHz), with particularly little spectrum in the mid frequency bands. There is, therefore, an asymmetry in overall spectrum. But behind this we note that even the MNOs with less overall spectrum have strengths in certain bands.
- 5.25 O2 and Vodafone have large amounts of low frequency spectrum, whereas H3G and BT/EE have relatively little. H3G, however, has a large amount of spectrum in the wider 3.4-3.8 GHz band as a result of its purchase of UK Broadband (which holds spectrum licences in this band) as well as the 20 MHz it purchased in the 2018 auction.
- 5.26 In this auction, we will be awarding:
- 60 MHz of paired 700 MHz spectrum,
 - 20 MHz of downlink-only 700 MHz spectrum, and
 - 120 MHz of 3.6-3.8 GHz spectrum.
- 5.27 This additional spectrum represents an increase of around 22% of current overall spectrum holdings. The 700 MHz spectrum that we are awarding represents a substantial addition to the current low frequency holdings: it is equivalent to 47% of all currently held low frequency spectrum, including 1400 MHz in this pool (and 62% of all sub-1GHz spectrum). The 3.6-3.8 GHz spectrum we are awarding is equivalent to 44% of all spectrum in the wider 3.4-3.8 GHz band that is currently allocated.

⁸⁰ Annex 8 discusses the timings for each spectrum band becoming useable.

⁸¹ Shares of allocated spectrum, as presented in Figure 5.2, are not meaningful from a competition perspective. What matters is shares of all spectrum that is useable at a given time. Nonetheless, we present all spectrum for which MNOs hold licences, whether it is useable now or in future, as context for our competition assessment.

Figure 5.2: UK mobile spectrum holdings⁸²

Framework for evaluating competition concerns

5.28 Our analysis consists of the following steps:

- We consider which auction outcomes might give rise to competition concerns. By this, we mean post-auction distributions of spectrum holdings that could weaken future competition in the mobile market. For example, we might be concerned if an operator with a large amount of existing spectrum were to win all of the spectrum awarded in the auction. (Step 1)

⁸² H3G spectrum takes account of the granted licence variation requested by UK Broadband.

- We consider the potential severity of the effect on competition if these outcomes were to occur. For example, how detrimental it might be if O2 were to win no spectrum in the auction, or if BT/EE were to win all of the spectrum awarded. (Step 2)
- We consider how likely it is that those outcomes would arise as a result of bidders' behaviour in the auction in the absence of any measures (such as caps). As part of this, we consider the bidders' likely value for the spectrum – either for the use they could make of it in supplying mobile services, or for strategic reasons in denying that spectrum to rivals. (Step 3)
- Using the previous steps in the analysis, we then set out which competition concerns are most relevant for the current auction. (Step 4)
- We then consider what measures we should impose to address our concerns and set out our conclusions on what would be an appropriate and proportionate approach. (Step 5)

5.29 This approach is consistent with the framework we used in the competition assessment for the 2.3 and 3.4 GHz auction⁸³ and the 4G auction.⁸⁴

5.30 We briefly discuss the principles behind each of these stages, then present the analysis on our specific competition concerns.

Auction outcomes that might give rise to competition concerns (Step 1)

Dimensions of competition

- 5.31 There are various factors which influence an MNO's ability to compete effectively with its rivals. These include: capacity, speeds experienced by users, coverage, services and features, pricing, brand image, marketing and customer service.
- 5.32 In annex 6, we consider which aspects of mobile services are most important to customers. We note that consumers value various elements of an MNO's service and do not choose a provider based on one dimension alone (i.e. only price or only coverage).
- 5.33 According to Ofcom research on consumer engagement, the key drivers of customers' decisions in choosing a mobile operator are price and network quality, followed by customer service and handset range.
- 5.34 Network quality can be broken down into several factors. According to analysis by Enders, the most important factors for customers are network reliability and coverage. These two factors are somewhat interrelated, since dropped calls or lack of service could form part of network reliability. An Enders survey into which aspect of network quality was most important showed that, in July 2017, 'reliability' was the most important (48%), followed by coverage (33%) and then data speeds, which are increasing in importance but still

⁸³ https://www.ofcom.org.uk/data/assets/pdf_file/0022/103819/Statement-Award-of-the-2.3-and-3.4-GHz-spectrum-bands-Competition-issues-and-auction-regulations.pdf, chapters 6 and 7.

⁸⁴ https://www.ofcom.org.uk/data/assets/pdf_file/0031/46489/statement.pdf, paragraph 4.32.

behind the other factors (14%, up from 9% in 2014). According to Ofcom consumer research, web browsing is clearly the most important mobile service for customers, followed by calls and then by video streaming.⁸⁵

5.35 In the competition assessment for this auction, we focus our analysis on those dimensions of competition which are (at least in part) affected by an MNO's spectrum holdings. These are:

- Capacity – the ability to supply users with good quality voice and data services;
- Coverage – the extent to which customers can receive good quality services where they live, work and travel;
- Certain services and features – for example, the ability to deploy 5G, or offer high peak speeds.⁸⁶

5.36 Capacity and coverage both impact directly on reliability, which, as noted above, is one of the most important aspects of network quality for consumers. Having sufficient **capacity** is important because the amount of capacity (for a given number of users of a network) determines the average data speeds those users receive. Capacity can be increased by, among other things, deploying additional spectrum. Some types of spectrum, for example mid frequency spectrum between 1800 MHz and 6 GHz, may be better suited to providing capacity than others.

5.37 **Coverage** can be provided by spectrum in any band, but low frequency spectrum is particularly useful for achieving good quality coverage cost-effectively across wide areas and in harder-to-serve locations (such as deep indoors). Holdings of low frequency spectrum are currently more asymmetric than of overall spectrum. This auction may be the last opportunity for some time for MNOs to obtain a significant amount of low frequency spectrum, unless they acquire it through spectrum trading. As such, a significant asymmetry in low frequency spectrum after the award could be a cause for concern.

5.38 In terms of **services and features** that MNOs can offer, we particularly focus on the development of 5G. We expect that, in the short term, 5G deployments will focus on enhanced mobile broadband (eMBB), i.e. improvements to network performance.⁸⁷ In the longer term we expect that MNOs might want to use 5G technology to offer other types of services (e.g. those taking advantage of other features available to 5G such as deployments for massive machine types of communication, e.g. Internet of Things (IoT), and low latency) and that this is likely to become important to an MNO's ability to compete with its rivals. All of the spectrum we are awarding in this auction is in the bands we have previously identified as key 5G bands⁸⁸ and where we expect initial 5G NR deployments to take place (though we note 700 MHz could be used first for LTE deployments). We also expect that other current mobile bands will be used for 5G services at some point.

⁸⁵ In terms of the percentage of people who rated these services 'extremely' or 'very' important.

⁸⁶ Peak speeds are the maximum speeds that customers can achieve for data intensive services in ideal conditions.

⁸⁷ We note that MNOs may also use 5G to offer FWA services though we do not consider this relevant for our competition assessment as explained below.

⁸⁸ https://www.ofcom.org.uk/_data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

- 5.39 Other features, often used for marketing purposes, relate to peak (headline) speeds. Large quantities of spectrum, as well as more efficient technologies such as 4G and 5G, allow operators to offer and advertise very fast downlink speeds. These peak speeds are achieved in ideal conditions, when the network is only lightly loaded and users are close to the transmitting base station. In reality, consumers are likely to care about the range of actual speeds they experience, and not about theoretical peak speeds.⁸⁹
- 5.40 In this auction, we are awarding spectrum in the 700 MHz and 3.6-3.8 GHz bands. We therefore consider MNOs' overall holdings of mobile spectrum, plus shares of low frequency bands, and, additionally, other bands which may have similar properties to the 3.6-3.8 GHz band.
- 5.41 Given the distribution of spectrum holdings (as shown in Figure 5.2 above), an MNO that may be weaker in certain dimensions of competition – as a result of having less of a particular type of spectrum – is likely to have compensating strengths in other areas when competing for customers due to larger holdings of other types of spectrum.
- 5.42 In addition, the current distribution of spectrum holdings means there may be potential gains from trading spectrum in the future. To give an example: MNO A, with little low frequency spectrum, may have a higher marginal value for additional spectrum in this band than MNO B which has a large amount of low frequency spectrum; MNO B, conversely, may have a higher value for mid frequency spectrum than MNO A due to asymmetric holdings in that band.

How harmful is the potential effect on competition? (Step 2)

- 5.43 As part of identifying outcomes which may be of concern, we consider how harmful the effect on competition might be if they were to occur. That is, would it be likely that competition was significantly weakened as a result or not?
- 5.44 We have outlined above how different spectrum allocations can potentially affect the ways in which the MNOs compete on these various dimensions. A large asymmetry in spectrum holdings – either overall or in a particular type of spectrum – might weaken competition between the MNOs. Certain outcomes of the auction would lead to a more asymmetric distribution of spectrum and might be detrimental to competition. We consider the potential magnitude of these negative effects.

⁸⁹ We note in annex 9 that in a recent report from OpenSignal on consumer experience of video services the analysis shows that high speeds do not necessarily equate to a good video experience. For example, South Korea had the highest overall download speed (over 5 Mbit/s ahead of its closest rival) but it only achieved 16th place in the overall video experience analysis, whereas Czech Republic was rated as the top country for video experience but was not in the top ten countries for overall download speed. <https://opensignal.com/reports/2018/09/state-of-mobile-video>

Assessment of likelihood of outcomes (Step 3)

- 5.45 In line with our duties, we want to allocate spectrum in a way that leads to an efficient use of this scarce resource and promotes competition. We consider that auctioning the spectrum is generally the best way to achieve this.
- 5.46 In an auction, the spectrum ought to be acquired by the bidder who has the greatest value for it. There may be circumstances, however, when allocating the spectrum to the MNO with the highest value can result in an allocation that weakens competition.
- 5.47 We distinguish two sources of value (i.e. profits) for MNOs when bidding for spectrum:⁹⁰
- **Intrinsic value** – the present value of additional profits a bidder expects to earn when holding the spectrum, compared to not holding it, from using it to supply (additional or improved) services to consumers.
 - **Strategic investment value** – the present value of additional expected profits earned from bids that deprive competitors of spectrum and therefore affect the future structure of competition in mobile services.
- 5.48 Bidding based on a high intrinsic value may still result in an allocation of spectrum that could weaken competition. In this case, there may be a trade-off for consumers between benefits from the spectrum going to the MNO which will make the best use of it, and weaker competition as a result of a more asymmetric allocation of spectrum. The net benefit may be positive or negative for consumers.
- 5.49 Where the bidding is based on strategic value, there is generally no trade off and the outcome is likely to be harmful for consumers.
- 5.50 When assessing the likelihood of outcomes which may cause concern, we consider the possibility of bids based on intrinsic value and strategic value.

Intrinsic value for spectrum

- 5.51 An MNO's intrinsic value for spectrum will depend on the benefit the MNO can obtain from using the spectrum and the costs of deploying it. Benefits could arise either from being able to increase revenues (for example by supplying improved services that attract new subscribers or increased revenue per subscriber), or from reduced costs in supplying these services.
- 5.52 The costs of deploying the spectrum will depend on the additional equipment needed to make use of it and on the MNO's existing network configuration.
- 5.53 In this auction, we are also proposing to award two coverage obligations. As explained in section 7, bidding would be in the form of packages, which would include spectrum lots and, if desired, coverage lots. Our proposed auction design would allow MNOs to obtain a discount on its spectrum package by acquiring a coverage obligation. Our proposed auction

⁹⁰ Even if MNOs do not necessarily make the distinction between these two sources of value in an explicit way when formulating their own valuation of spectrum, it is relevant for our analysis.

design would allow MNOs to obtain a discount on its spectrum package by acquiring a coverage obligation. It is possible that there could be a change in the allocation of spectrum, compared to an auction without coverage obligations, as discussed in section 7.

Strategic investment can be costly and difficult to coordinate

- 5.54 Strategic investment occurs when an MNO bids in excess of its own intrinsic value for an amount of spectrum with the aim of denying that spectrum to competitors. Strategic investment may be attempted by a single bidder (unilaterally) or through tacit coordination between two or more bidders.
- 5.55 Tacit coordination occurs when, without discussing it or reaching an agreement, two or more MNOs combine their bids for spectrum in order to deny the spectrum to a rival. This can lower the cost of strategic investment by sharing this cost with other MNOs – but it can be difficult to achieve due, for example, to a lack of information on spectrum valuations or the inability to find a target outcome or a focal point of spectrum allocations to coordinate bids.
- 5.56 We anticipate that our proposed auction format of a CCA with limited information policy between clock rounds and a final sealed-bid round in the principal stage would make tacit coordination to exclude other bidders particularly difficult.⁹¹
- 5.57 We also consider that, now that spectrum is more evenly allocated than prior to the 2.3 and 3.4 GHz auction, there is less of an obvious target for coordination than there was in that auction – when it was generally believed that there might be competitive advantages in denying spectrum to bidders with a particular need to increase capacity.
- 5.58 The incentive for a bidder to engage in strategic investment will depend on the cost and the pay-off of winning the spectrum. The cost will, in general, depend on the amount that an MNO needs to outbid its target to win the spectrum.
- 5.59 If a rival has a high (intrinsic) value for the spectrum then strategic investment is likely to be extremely costly, especially if the strategic investor has a low value for the spectrum itself, aside from the strategic motive. The cost may be especially high if there is plenty of spectrum available in the auction, as there is here (the spectrum in the award is equivalent to around 22% of current overall spectrum holdings).
- 5.60 The pay-off will depend on the rival's competitive position being sufficiently weakened by being denied the spectrum, such that the strategic investor will be able to win customers or raise prices. If the rival has alternative means to maintain its competitive position – for example because it has considerable spectrum holdings in other frequencies or can build more mobile sites to increase coverage – then strategic investment is unlikely to be profitable.

⁹¹ The clock round and principal stage is explained fully in section 7.

Which competition concerns are most relevant (Step 4)?

- 5.61 We assess this by considering a combination of the severity of the potential outcome if it were to occur and the likelihood that it will occur.
- 5.62 For example, we would be very concerned if there were a risk that an MNO would cease to be a credible competitor in the market. Nonetheless, if we consider that this is not a potential **outcome** of the auction then we do not consider it as an overall concern and do not impose any measures to address it.

Framework for assessing measures (Step 5)

- 5.63 The measures we impose to address any competition concerns must be proportionate. In order to evaluate this, we consider whether the measure is:
- Appropriate – it must be effective in achieving the aim in question;
 - Necessary – it must be no more onerous than is required to achieve that aim;
 - The least onerous of all equally effective measures; and
 - Not likely to produce adverse effects which are disproportionate to the aim being pursued.
- 5.64 In considering the effectiveness and potential downsides of the different options, we need to recognise the uncertainty that is an inevitable aspect of this forward-looking competition assessment. There are uncertainties, for example, over the potential effects of spectrum asymmetries, the likelihood of concerns arising without measures to prevent them and whether competition measures might unintentionally lead to a worse outcome for consumers.
- 5.65 These uncertainties mean that making decisions on the proportionality of the different options involves a measure of judgement.
- 5.66 We note that there may be a risk of adverse effects as a result of intervention. There are various ways in which competition measures may prevent an outcome that would be beneficial to consumers, for example:
- Restricting an MNO from buying spectrum may increase its costs or reduce its quality of services;
 - If there is a spectrum cap but those eligible to bid are not willing to pay the reserve price, then there may be unsold spectrum. This would delay the spectrum becoming available;
 - If there is a spectrum reservation but those eligible to bid do not wish to purchase the spectrum at the auction price, there may be unsold spectrum;
 - There is a risk that MNOs may choose to bid less than their intrinsic value in order to influence future decisions by Ofcom, i.e. achieve reservations and/or caps which would entail fewer bidders for certain spectrum in the future.

- 5.67 In general, the risk of harm from intervention increases as the level of intervention increases. We are proposing a relatively light degree of intervention in this auction – a single overall cap which is not particularly restrictive but achieves our objective of preventing outcomes which may have a negative effect on competition.
- 5.68 We now present our analysis and provisional conclusions on the potential competition concerns.

Potential competition concerns

- 5.69 When considering which auction outcomes might give rise to competition concerns there are two broad types of concern.
- 5.70 Our most serious potential concern is that one or more operator(s) might have a sufficiently small share of spectrum post-auction that they **cease to be credible**. That is, they would not exert an effective competitive constraint on rivals and so contribute to the overall competitiveness of the market (even if they do not exit the market). We consider it important that there remain at least four credible MNOs.
- 5.71 A second type of concern is where the auction results in **an allocation of spectrum which is significantly asymmetric and could potentially weaken competition** between MNOs. We may be concerned about the negative effects of very asymmetric spectrum shares on competition, even if we expect all operators to remain credible whatever the outcome of the auction. Competition problems due to asymmetry can arise from either one operator having a particularly large share of spectrum or from an operator having a particularly small share.
- 5.72 We have identified a number of potential competition concerns:
- **Competition concern 1:** The likelihood of there ceasing to be four credible MNOs as a result of the auction.
 - **Competition concern 2:** The likelihood of very asymmetric mobile spectrum shares weakening competition (even if there are four credible MNOs) through:
 - a) Asymmetry in overall spectrum
 - b) Asymmetry in ‘capacity’ spectrum
 - c) Asymmetry in ‘spectrum that can be used for 5G’, 3.4-3.8 GHz spectrum in particular
 - d) Asymmetry in low frequency spectrum
- 5.73 We consider that all MNOs will have sufficient spectrum portfolios to remain credible whether or not they acquire any spectrum in this award. The bulk of our analysis, therefore, focuses on our potential concerns due to asymmetric spectrum holdings. We begin with this discussion before returning to the question of credibility.

Competition concern 2a: The risk of highly asymmetric overall spectrum shares

- 5.74 In summary, in light of the risk that competition may be weakened due to very asymmetric shares of overall spectrum, we propose to impose a cap of 416 MHz (37%) of overall spectrum.
- 5.75 Below we present our analysis of this competition concern: we assess the risks to competition arising from asymmetric spectrum shares, the possible auction outcomes that would worry us and their likelihood. Here we consider potential asymmetries in total spectrum, taking into account the total MHz held by each MNO on the basis that all spectrum can be used to provide capacity. Concern 2b (below) more specifically considers asymmetry in mid frequency and downlink spectrum, both of which may be particularly useful for adding capacity.

The risks to competition from asymmetric spectrum shares

- 5.76 We consider the UK mobile market is generally working well, with four credible MNOs and a range of MVNOs supporting strong retail competition, despite the fact that the existing spectrum holdings of the four MNOs have been fairly asymmetric during the period that we have assessed.
- 5.77 Nonetheless, we would be concerned if increased spectrum asymmetry weakened competition between MNOs, particularly if large asymmetries were to persist in the medium to long term. As described in annex 6, we expect a large increase in data growth in the future. Cisco estimated that UK mobile data traffic would grow six-fold from 2016 to 2021, a compound annual growth rate of 43% and indeed the monthly average consumption of mobile data grew at a rate of 46% between 2016 and 2017, and at a rate of 49% p.a. since 2017.^{92,93}
- 5.78 Data growth will require increasing capacity in order for MNOs to continue to provide a good quality of service to mobile consumers in a cost-efficient manner. There are different ways operators could potentially meet these needs, but deploying additional spectrum is likely to be an important means.
- 5.79 Although it is, in one sense, absolute spectrum holdings that determine an MNO's capacity to supply its customers, spectrum shares also matter. A large difference in the relative holdings of spectrum could influence competition between the MNOs. Competition may be weaker either if one (or more) MNO has a very high share of spectrum, or one (or more) MNO has a very low share, though we do not consider that symmetrical shares of spectrum are necessary for competition to work well.

⁹² https://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/#~Country

⁹³ The average volume of data consumed per subscriber per month was 1.9GB in 2017, up from 1.3GB in 2016. It was 0.87GB in 2015, https://www.ofcom.org.uk/data/assets/pdf_file/0024/108843/summary-report-connected-nations-2017.pdf

- 5.80 As set out below, asymmetries in spectrum holdings are not negative per se. They can, in certain instances, be positive for competition and give rise to consumer benefits; they may reflect differences in operators' commercial strategies and expectations about the future. We are therefore only concerned about large asymmetries.
- 5.81 In general, we are also more concerned about significant asymmetries that persist in the medium to longer term than in the very short term, particularly as we do not currently have any plans to award further low frequency and mid frequency spectrum in the medium term.

Competition may be weaker if one (or more) MNO has a very high share of spectrum

Unmatchable competitive advantage

- 5.82 Competition may be weaker if one MNO has such a high relative share of spectrum that it is able to offer sufficiently superior services that its rivals are unable to replicate. For example, the MNO with much more spectrum might be able to offer noticeably faster data services or may offer a more consistent quality of service to a higher number of users competing for fast data services, and others might lose customers as a result.
- 5.83 While there may be some benefits to consumers from having this superior service from one MNO, this could be against consumers' interests in the longer term. With weaker competition, prices may rise or service quality may suffer without a compensating fall in prices. The harm to competition, and to consumers as a whole, could outweigh these benefits.

Spectrum hoarding

- 5.84 An MNO with a very high spectrum share could in principle make limited use of any additional spectrum it wins in an auction, whilst other MNOs with less spectrum might have put it to more immediate or productive use. This could weaken competition in the short and longer term: the other MNOs might have competed more strongly if they had instead won the auctioned spectrum.

Excess spectrum capacity distorting the market

- 5.85 There is a risk that an MNO with a very high spectrum share could credibly threaten to respond with aggressive price cuts if rivals sought to grow their market share of different services or customer segments through lower prices.
- 5.86 For example, it could have additional network capacity in place to be able to absorb an increase in its customer base quickly if it won a significant number of customers from its competitors. The threat of provoking such a response may put rivals off seeking to compete more aggressively, and lead to a softening of competition for some services.
- 5.87 If the MNO with spare capacity became the only viable alternative for prospective MVNOs (because others did not have sufficient capacity to supply them) this could soften wholesale competition, which in turn would have adverse effects on retail competition.

Greater ability to launch new services without affecting existing services

5.88 An MNO with much greater relative capacity may be able to launch new services before its competitors. For example, it could use its spare spectrum to launch certain types of 5G services, leaving its other services unaffected, whereas rivals might need to re-purpose some of their existing deployments, potentially to the detriment of their legacy services. Again, although customers of the MNO with a very high spectrum share might benefit from earlier availability of new services, there could be weaker competition and overall consumer harm in the longer term.

Competition may be weaker if one or more MNOs has a relatively small share of spectrum

5.89 In mobile networks, providing adequate network capacity means serving mobile users with a minimum quality of service.⁹⁴ The capacity of a network depends on the available spectrum bandwidth, the site and sector density (how many sites and how many sectors per site transmit in a given area), and the spectral efficiency of the technologies used.⁹⁵

5.90 Operators can add network capacity in several ways. They can:

- deploy additional spectrum;
- build additional network sites or use small cells, femto-cells and repeaters (network densification).
- increase the number of sectors per site (sector densification);
- make use of more efficient technologies, such as 4G and 5G;
- use more efficient antenna technologies such as beamforming and massive MIMO;
- offload traffic to alternative radio technologies such as Wi-Fi; and
- use traffic management techniques to ensure overall users' quality of service is not deteriorated in peak hours.

5.91 All these methods can increase the total capacity of cellular sites and provide higher average speeds to mobile users. MNOs with lower shares of licensed spectrum than rivals may therefore be able to deliver comparable levels of capacity by relying on approaches other than by deploying additional spectrum.

5.92 Rolling out the spectrum bands in the award will enable MNOs to offer additional capacity but is also likely to incur substantial network costs involving the replacement of new antennas, possibly active antenna systems, the strengthening of masts to accommodate these changes etc.

⁹⁴ Network capacity is measured in bits per second and refers to the rate being made available by cellular sites to satisfy customers' demand for data transmission.

⁹⁵ Spectral efficiency refers to the information in bits per second that can be transmitted using one Hertz of spectrum. It is measured in Bits/s/Hz or Bit/s/Hz/cell.

- 5.93 Some of the alternative methods to increase capacity can take a long time to deploy, can be technically challenging or may cost more than acquiring and deploying additional spectrum.
- 5.94 Building new sites in some locations can be challenging, due in part to a lack of suitable sites in the right locations and to planning restrictions, and there may be practical constraints on re-farming spectrum rapidly. This means some of these other solutions to adding capacity may not be very effective over a short period, and that competition may therefore be weaker as a result of one or more MNOs having relatively low spectrum shares.
- 5.95 MNOs with small spectrum holdings with no access to new spectrum will tend to have higher marginal costs of adding capacity than operators with a large amount of spectrum. This is because they would need to build significantly more sites to increase capacity (whereas the operator with a high spectrum share could, for example, deploy additional spectrum on its existing sites with lower associated equipment costs). As a result, an MNO with a low share of spectrum could have reduced incentives to compete aggressively for new customers given the costly investment in sites that would be required to serve additional customers.
- 5.96 In general, therefore, spectrum holdings may be reflective of an MNO's ability to serve mobile users with a minimum quality of service and competition could be weaker if one or more MNOs had a relatively low share of overall spectrum.

Symmetrical spectrum shares are not necessary

- 5.97 MNOs do not need to have the same, or close to the same, shares of spectrum in order for there to be strong competition. This is because:
- a) There is no reason to expect rivals in any market to need the same capacity in order for competition to be strong. MNOs can have different market shares (that is, need different amounts of capacity to serve their customers well), may have compensating strengths in other areas (e.g. customer service), or may still be able to deliver services to many consumers by choosing commercial strategies that make best use of their capacity.⁹⁶
 - b) As noted above, spectrum is not the only way of adding capacity or improving services. Capacity can be added in many other ways, though these alternative means of increasing capacity may cost more or take longer than using additional spectrum. For example, we note that H3G has the second highest share of data traffic, despite having relatively low spectrum holdings of currently useable spectrum (and by far the highest share of data traffic per subscriber and per MHz of spectrum held).⁹⁷

⁹⁶ However, we recognise that if very restrictive commercial strategies are adopted to cope with limited capacity, then competition for some users may become weaker.

⁹⁷ See Figures A6.30, A6.31 and A6.32 (annex 6). H3G has also said: "Three's customers are particularly data-hungry, already using 3.5x more data per month than the industry average."

<http://www.threemediacentre.co.uk/news/2018/three-UK-committed-to-invest-into-5g.aspx>.

- 5.98 A degree of asymmetry in overall spectrum holdings may give rise to consumer benefits. For example, an operator with a large share of spectrum may use any additional spectrum in an innovative way, and an operator that has a lower share of spectrum may find innovative ways of attracting consumers to compensate e.g. targeting particular consumer groups or business segments, or by offering higher quality in other aspects of service.

What degree of asymmetry raises concerns?

- 5.99 If all four MNOs had an equal share of spectrum, they would all have 25%. We do not consider that it is necessary for each MNO to have around 25% of spectrum for competition to work well.
- 5.100 In its responses to consultation on the 2.3 and 3.4 GHz award, H3G argued that, to maintain a four-player market structure, each MNO's spectrum share needed to be between a 20% floor and a 30% ceiling. We said that this was too restrictive because we do not consider that symmetrical shares are necessary.⁹⁸
- 5.101 If BT/EE were to win all of the spectrum to be awarded in this auction, its share of overall spectrum would rise to 44%. We consider that this is above the threshold where we would have concerns.
- 5.102 We consider that a share of around 40% of overall spectrum may raise competition concerns. In a four-player market, if one MNO has a 40% share, then the other three MNOs will each have 20% of overall spectrum on average. The MNO with 40% of overall spectrum therefore has twice as much as the average of its rivals. We consider that some of the detrimental effects on competition outlined above may arise at this level of asymmetry.
- 5.103 In the context of potential competition measures in an auction, it is necessary to be more specific than 'around 40%' and set a cap at a particular level. In the 2013 4G auction,⁹⁹ we set a cap of 2 x 105 MHz of overall spectrum, which was equivalent to 37%. This was because of concerns that a more asymmetric distribution than this could weaken competition. After that auction, EE's share of spectrum was 37%. It then rose to 42% on merging with BT (completed in early 2016).
- 5.104 In the 2016 consultation on the competition assessment for the 2.3 and 3.4 GHz auction,¹⁰⁰ we said that we considered that a share of 'around 40%' of overall spectrum might still raise competition concerns. In the July 2017 statement, we were more specific and outlined our judgement that a 37% share was generally an appropriate limit,¹⁰¹ in line with the cap in 2013.

⁹⁸ July 2017 statement, paragraphs 6.46 onwards.

⁹⁹ https://www.ofcom.org.uk/data/assets/pdf_file/0027/55395/statement-summary.pdf, paragraph 1.11.

¹⁰⁰ https://www.ofcom.org.uk/data/assets/pdf_file/0022/103819/Statement-Award-of-the-2.3-and-3.4-GHz-spectrum-bands-Competition-issues-and-auction-regulations.pdf, paragraphs 4.30 to 4.36.

¹⁰¹ https://www.ofcom.org.uk/data/assets/pdf_file/0022/103819/Statement-Award-of-the-2.3-and-3.4-GHz-spectrum-bands-Competition-issues-and-auction-regulations.pdf, paragraphs 6.46 to 6.53.

- 5.105 We recognise that being more specific involves the exercise of regulatory judgement. We consider that the 37% share at which we imposed an overall cap in the 2013 4G auction and the 2018 2.3 and 3.4 GHz auction is generally an appropriate limit.
- 5.106 We do not consider that 37% represents an absolute, cliff-edge threshold to the extent that any share up to this level is perfectly acceptable and a share above would necessarily cause an immediate and severe weakening of competition. We consider, however, that having one or more MNOs with a spectrum share above around 40% for a sustained period is likely to weaken competition, and that 37% represents an appropriate limit to safeguard competition.
- 5.107 It remains our judgment that competition concerns about asymmetry in relation to capacity and average speeds may generally arise when one MNO has around 37% of overall spectrum.

Step 1 - What outcomes might we be worried about?

- 5.108 In light of the above, we might potentially be concerned if, after the auction, one (or more) MNO had a very large share of overall spectrum and/or one (or more) MNO had a very small share.
- 5.109 In the 2.3 and 3.4 GHz auction in 2018, we were concerned that BT/EE might gain an unmatched competitive advantage if it won too much spectrum, and that at least one MNO might face capacity constraints if it were to win none.

Spectrum shares are less asymmetric than before

- 5.110 As a result of the 2.3 and 3.4 GHz auction in April 2018, overall spectrum shares are less asymmetric than they were – both now and going forward. Figure 5.3 presents spectrum shares in different periods and illustrates this. It also shows how the spectrum we will award may affect future shares.

Figure 5.3: Spectrum shares in various periods



- 5.111 **Period A** is prior to the 2.3 and 3.4 GHz auction, when there was considerable asymmetry in the UK mobile market. In this period, BT/EE had a 42% share of overall spectrum, and O2 just 14%.
- 5.112 **Period B** shows the shares of currently useable spectrum, including the 2.3 GHz band (but excluding the 3.4 GHz band).¹⁰² O2's share has increased because it won all 40 MHz of the 2.3 GHz spectrum available. O2 began deployment of its 2.3 GHz holdings immediately after it was awarded this spectrum.¹⁰³ BT/EE's share is 39% of overall spectrum at present.
- 5.113 **Period C** reflects all of the spectrum that was awarded in the 2.3 and 3.4 GHz auction, plus the 3.4 GHz and 3.6 GHz spectrum that H3G (and UK Broadband) already held. As noted above, this is not a relevant pool of spectrum for assessing competition because we expect that other (currently unallocated) spectrum will become useable in the same timeframe as the 3.4 GHz and H3G's 3.6 GHz. Nonetheless it shows shares of currently held spectrum.
- 5.114 **Period D** also includes all of the spectrum that we will award in this auction: the 700 MHz (paired and downlink-only) and the 3.6-3.8 GHz spectrum.

We are still concerned about potential asymmetric spectrum holdings in the future

- 5.115 Although spectrum shares have become less asymmetric than before the 2.3 and 3.4 GHz auction, they remain asymmetric. As we outline in annex 6 (paragraphs A6.36 to A6.48), UK spectrum shares are more asymmetric (on various measures) than those in other European countries with four MNOs, even taking into account the award of the 2.3 GHz band in 2018.¹⁰⁴ Ofcom has found that the highest share of overall spectrum in other comparable four-player European markets ranges from 28% to 32%.

¹⁰² As noted above, we expect the 3.4 GHz spectrum to be useable in 2019, once handsets are available.

¹⁰³ <https://news.o2.co.uk/press-release/o2-to-connect-1000-locations-to-latest-4g-spectrum-in-rapid-roll-out/>

¹⁰⁴ When we take into account that 3.4 GHz that has been awarded, asymmetry in the UK is comparable to that in Spain and the Netherlands, and among the highest in Europe. However, as noted above, the 700 MHz paired spectrum and part of the 3.6-3.8 GHz band will be useable in the same timeframe but are not yet allocated, so we do not know how asymmetric holdings will be during this period.

- 5.116 As already noted, if we did not impose any competition measures on overall spectrum in this auction, BT/EE could increase its spectrum share to 44%. This is considerably above the 37% threshold at which we start to have concerns.
- 5.117 If O2 won no spectrum in this auction, then its share would be 15% of overall spectrum. We have previously considered there is a material risk of an MNO not having sufficient spectrum to be credible if it holds less than 10 to 15% of overall spectrum. Although its share would be at the top end of this range, we consider that O2 could potentially have considerably lower capacity than its rivals with this share of overall spectrum, especially if BT/EE were able to obtain a 44% share of overall spectrum.
- 5.118 We do not have a particular concern about Vodafone or H3G winning a large amount of the spectrum to be awarded. Nonetheless, if either of them won *all* the spectrum, we would be concerned, as Vodafone's share of overall spectrum would reach 38% and H3G's would be 39%.
- 5.119 We are not concerned about Vodafone or H3G winning none of the spectrum available, as their shares of overall spectrum would be 20% and 21% respectively in this event. We consider that they would each have sufficient shares of overall spectrum to be effective competitors in the market.

Step 2 – How serious would it be if the potentially concerning outcomes occurred?

- 5.120 Although we consider that perfect symmetry in spectrum shares is not necessary for competition to work well for consumers, we would be very concerned if any MNO won a large amount of the spectrum in the auction, taking its share above 37% for a sustained period of time. We consider that there is a significant risk that competition would be weakened if any MNO's share of overall spectrum rose above 37%, particularly if this share were to endure for the medium to longer term.
- 5.121 Although BT/EE's share of useable spectrum is currently more than 39%, this will fall to 35% once 3.4 GHz spectrum becomes useable from 2019 (as a result of competition measures imposed in the previous auction). However, BT/EE's spectrum share has the potential to increase above 37% again if it were to acquire a significant quantity of spectrum in the forthcoming award. We would have concerns if this share were to persist in the longer term.
- 5.122 Competition may also be weakened if O2 did not win any spectrum, though this is less certain. We consider that O2 would have sufficient spectrum to remain a credible operator if it won no spectrum in this auction. [REDACTED], and O2 will have a 15% share of overall spectrum even if it does not win any spectrum in this award.
- 5.123 The higher the share of the largest spectrum holder, the less spectrum is available for other operators. We consider that competition might be stronger if a credible operator with a share of spectrum in the 10 to 15% range gained a greater share.

Step 3 – How likely are these outcomes to occur?

- 5.124 We consider it is not particularly likely that BT/EE would win *all* the spectrum available in this auction, even without measures to prevent it. We are awarding 200 MHz of spectrum (80 MHz of 700 MHz and 120 MHz of 3.6-3.8 GHz) and it is likely to be costly for a single MNO to acquire it all, outbidding the intrinsic values of the other MNOs for any spectrum at all.¹⁰⁵
- 5.125 Nevertheless, we consider that BT/EE might well have a high intrinsic value for both 700 MHz (as it has little low frequency spectrum at present) and 3.6-3.8 GHz spectrum, which it could use to deploy a 5G service.
- 5.126 Without a cap, it is possible that BT/EE could acquire more than 120 MHz of the spectrum awarded, which would take its share of overall spectrum to more than 37%. We might be concerned about BT/EE winning more than 120 MHz, even if it did have the highest intrinsic value for the spectrum¹⁰⁶ as it would deny that spectrum to competitors with much smaller shares of overall spectrum.
- 5.127 We also consider that it is possible that O2 might not win any spectrum at all in this auction. However, if O2 would indeed be a weaker competitor without any spectrum from this award then it is likely to have a relatively high intrinsic value for this spectrum, and likely to be able to win it in the auction. On the other hand, if O2 really needs additional spectrum to be a strong competitor, then its rivals might benefit considerably from strategic bidding which denied this spectrum to O2.

Strategic investment

- 5.128 We consider whether strategic bidding might be likely to result in O2 winning none of the spectrum available as we consider that denying spectrum to the MNO with the lowest share is the most likely strategic aim of its rivals (in terms of overall spectrum).
- 5.129 **Unilateral** strategic investment against O2 would require one MNO to purchase all 200 MHz of spectrum available in the auction. This is likely to be extremely costly as the winner would need to outbid the other MNOs' intrinsic values for all of the spectrum.
- 5.130 We consider it highly likely that O2, Vodafone and BT/EE would all have a high intrinsic value for some 3.6-3.8 GHz spectrum, and that all four MNOs may well value some 700 MHz spectrum – either because they have little low frequency spectrum at present (BT/EE and H3G) or because they would use it to provide a 5G coverage layer in the shorter term.
- 5.131 Successful tacitly coordinated strategic investment could lower the cost for the MNO engaging in this practice by splitting it with another bidder. In general, such outcomes are difficult to achieve because they require two (or more) bidders to converge on their preferred outcome without explicit discussion. As noted above, the proposed auction

¹⁰⁵ It is worth noting that to buy ALL of the spectrum, the winner has to pay more for its 'final' 20 MHz than any other MNO would value its 'first' 20 MHz, as it needs to make sure that no other bidder wins any.

¹⁰⁶ Or if it won more spectrum as a consequence of winning a coverage obligation – see the discussion of the possibility of a change in the allocation of spectrum in section 7.

design, including coverage obligations, is likely to make this tacit convergence particularly difficult.

- 5.132 It is also not clear that the payoff would be particularly high from strategically excluding O2 from additional spectrum. We consider that O2 can be an effective competitor with its current spectrum holdings and its position would not be significantly weakened if it failed to acquire more [REDACTED].

Step 5 – We are proposing a 416 MHz (37%) cap on overall spectrum

- 5.133 We have said that we would be concerned if any MNO's share of overall spectrum rose above 37%, as this could weaken competition in the mobile market. This is most likely to be BT/EE and would occur if it bought more than 120 MHz of the spectrum being awarded in this auction.
- 5.134 We therefore propose a cap of 416 MHz (37%) of overall spectrum and believe this will function as a 'safeguard cap'.
- 5.135 Setting the level at 37% would be consistent with the level of the cap on overall spectrum that we imposed in the 4G auction and the 2.3 and 3.4 GHz auction, and therefore would promote regulatory certainty.
- 5.136 We consider that the proposed cap is **proportionate**, in that it is not very restrictive on MNOs' ability to purchase spectrum in this auction. As noted, BT/EE, the most restricted, could acquire 120 MHz of the 200 MHz to be awarded. H3G could acquire 185 MHz and Vodafone could acquire 190 MHz. O2 would not be restricted by the proposed cap. We have taken account of the minimum lot size in this award (5 MHz) and have decided to round up to the nearest feasible lot size that MNOs could acquire.¹⁰⁷
- 5.137 We also consider that the cap would be **effective**:
- As noted, it would prevent BT/EE's spectrum holdings from increasing to a point at which we would have competition concerns.
 - Although it would not ensure that O2 will acquire more spectrum, it makes this outcome more likely by restricting the amount that BT/EE can buy. BT/EE could not strategically invest (on its own) to prevent O2 from buying any spectrum in this auction.

¹⁰⁷ 37% of the 1116.9 MHz in the pool of useable spectrum is 413.3 MHz. Setting the cap at 413 MHz would allow BT/EE to purchase 118 MHz, Vodafone to purchase 187 MHz and H3G to purchase 183 MHz. Given that the smallest lot size is 5 MHz, these limits are effectively 115 MHz for BT/EE, 185 MHz for Vodafone and 180 MHz for H3G. This produces an implied cap of 36.7% or 36.8%. We feel that it is not proportionate to restrict MNOs to holdings below 37%. We therefore propose to set the cap at 416 MHz to allow for some rounding up rather than rounding down. We considered rounding the cap to 415 MHz (that is, the closest multiple of 5 MHz). However, current spectrum holdings are not in multiples of 5 MHz and this produces distortionary results. A cap of 415 MHz allows BT/EE to purchase 120 MHz, Vodafone to purchase 189 MHz and H3G to purchase 185 MHz. Given lot sizes, the effective maximum purchase for Vodafone would be 185 MHz which, at the limit, would allow it to hold 36.8% of overall spectrum, whereas the effective cap on BT/EE and H3G would be just over 37.2% and 37.1% respectively. We therefore propose to set the cap at 416 MHz (or 37.2%) of overall spectrum.

- It is possible that the 120 MHz maximum that BT/EE can acquire might act as a ‘focal point’ for strategic investment. That is, MNOs might believe that BT/EE would purchase up to its maximum, allowing them to know how much else they need to buy to exclude O2 from all spectrum. However, there would remain considerable uncertainty as to how BT/EE might split its purchase between the two bands, and how the remaining spectrum might be divided between H3G and Vodafone. We do not, therefore, consider that the cap would make coordinated strategic investment a more likely outcome.

5.138 We do not consider that a more restrictive measure is needed. As we have noted, spectrum distribution is more symmetric than it previously was. Since we consider that it is highly likely that all MNOs will have sufficient spectrum to allow them to remain credible even if they win no further spectrum in this auction, as discussed in more detail from paragraph 5.349 below, we do not propose any spectrum reservations.

We do not propose an interim cap

5.139 In setting a cap at a certain level of useable, or relevant, spectrum, we must consider which spectrum bands it is appropriate to include in this pool.

5.140 As we discuss in annex 8, we consider that:

- the 700 MHz paired spectrum will be useable in mid-2020;
- the 700 MHz downlink-only spectrum will be useable in mid-2020 or shortly after;
- Spectrum in the 3.6-3.8 GHz band will be useable in some parts of the UK before mid-2020, and possibly as early as 2019, subject to interim coordination requirements (see section 9 and annex 24 to account for existing users. Most of the users will have left the band by mid-2020, thereby making the band useable nationwide by this date with only some relatively minor deployment restrictions.¹⁰⁸ These deployment restrictions will be lifted if an agreement is reached with existing users.

5.141 We might consider imposing an additional interim cap if there were distinctive periods in which the pools of relevant spectrum were considerably different, and these periods were of sufficient duration to affect competition. In other words, such a cap might be proportionate if there was a risk that competition would be weakened if an MNO had a share above 37% for a sufficiently long interim period.

¹⁰⁸ Beyond mid-2020 the only incumbent user that could potentially affect deployment to any significant degree is a fixed link operating between the Isle of Wight and Portsmouth which is due to be cleared by the end of 2022. This link operates a 30 MHz carrier with a centre frequency of 3740 MHz. We have carried out a detailed analysis of this link (see annexes 8 and 15) and have concluded that, within a radius of 50 km of the link, roll-out of base stations is likely to be difficult with about 80% of the sectors we analysed failing to meet the protection criteria for this fixed link. For base stations further away, roll-out is likely to be minimally affected with about 4% of sectors analysed that lie within a few kilometres either side of the extended baseline of the fixed link (out to 200 km) failing to meet the protection criteria for the link. However, in this case the failure margin is relatively small (median margin ~3 dB) implying that with reasonable mitigation (e.g. a slight reduction in power or careful pointing) most of the sectors that failed (in our analysis) could in fact be deployed with minimal impact on network performance. The population potentially affected by this link is estimated to be c.500,000.

- 5.142 However, as we set out in annex 8 and annex 15, we believe that nearly all of the spectrum being auctioned will be useable by mid-2020 (or earlier) and, therefore, there is no need for an interim cap as there are no distinct periods of usability.

Competition concern 2b: The risk of very asymmetric shares in ‘capacity’ spectrum

Introduction and summary

- 5.143 Concern 2a above was particularly driven by the relationship between spectrum shares and the ability to provide capacity. In this sub-section, we consider whether certain spectrum is particularly well suited for providing capacity and whether the concerns over asymmetry considered in this way (i.e. with different weights for different types of spectrum) would be materially different from concerns over asymmetry in overall spectrum. We provisionally conclude that it would not be, and that no additional measures are required.
- 5.144 Recent technological developments (e.g. massive MIMO, beamforming, etc.) have the potential to significantly increase spectral efficiency and, therefore, the ability to enhance network capacity. These technologies are better suited to certain frequency bands – notably mid frequency bands¹⁰⁹, including the 3.6-3.8 GHz spectrum being auctioned¹¹⁰ – meaning it may be more cost effective to add capacity with certain frequency bands than others.
- 5.145 This auction therefore has the potential to introduce additional asymmetries in spectrum which may be particularly useful for adding capacity (‘capacity spectrum’). We would be concerned if asymmetries in this type of spectrum led to an operator having an unmatched advantage in adding capacity. However, we consider that any potential asymmetries in such ‘capacity spectrum’ are sufficiently addressed by our overall cap which restricts each MNO to a maximum of 37% of overall spectrum.
- 5.146 In addition, since mobile networks currently carry mostly data and most of this traffic is generated by users downloading content, we have looked at the potential for the auction to introduce asymmetries in downlink spectrum. We find that this is also largely addressed through our proposed cap on overall spectrum.
- 5.147 We do not, therefore, propose to adopt any measure beyond our proposed overall cap to address concerns over ‘capacity’ or downlink spectrum.

¹⁰⁹ As we discuss in detail in annex 8, we consider mid frequency bands to be those at or above 1800 MHz and below 6 GHz. However, in practice, not all mid frequency bands will be able to benefit from these technological developments in the same way. For example, the size of massive MIMO antennae is inversely proportional to frequency, with higher frequencies using smaller antennae. Therefore, deploying massive MIMO using frequencies such as 1800 MHz may be challenging as it would require much larger and heavier antennae than 3.4-3.8 GHz. We note however that it would still be possible to deploy MIMO technologies on this band, by reducing the number of antenna elements in the MIMO deployment.

¹¹⁰ For example, massive MIMO is only likely to be used in mid frequency bands as it would require significantly larger and heavier antennae for low frequency spectrum, that is bands at and above 1800 MHz. Furthermore, TDD bands including 2.3 GHz, 2.6 GHz unpaired and 3.4-3.8 GHz could allocate resources in a way that better reflects actual download/upload traffic profiles compared to FDD bands where spectrum is evenly split between download and upload.

Step 1 - Which outcomes raise concern

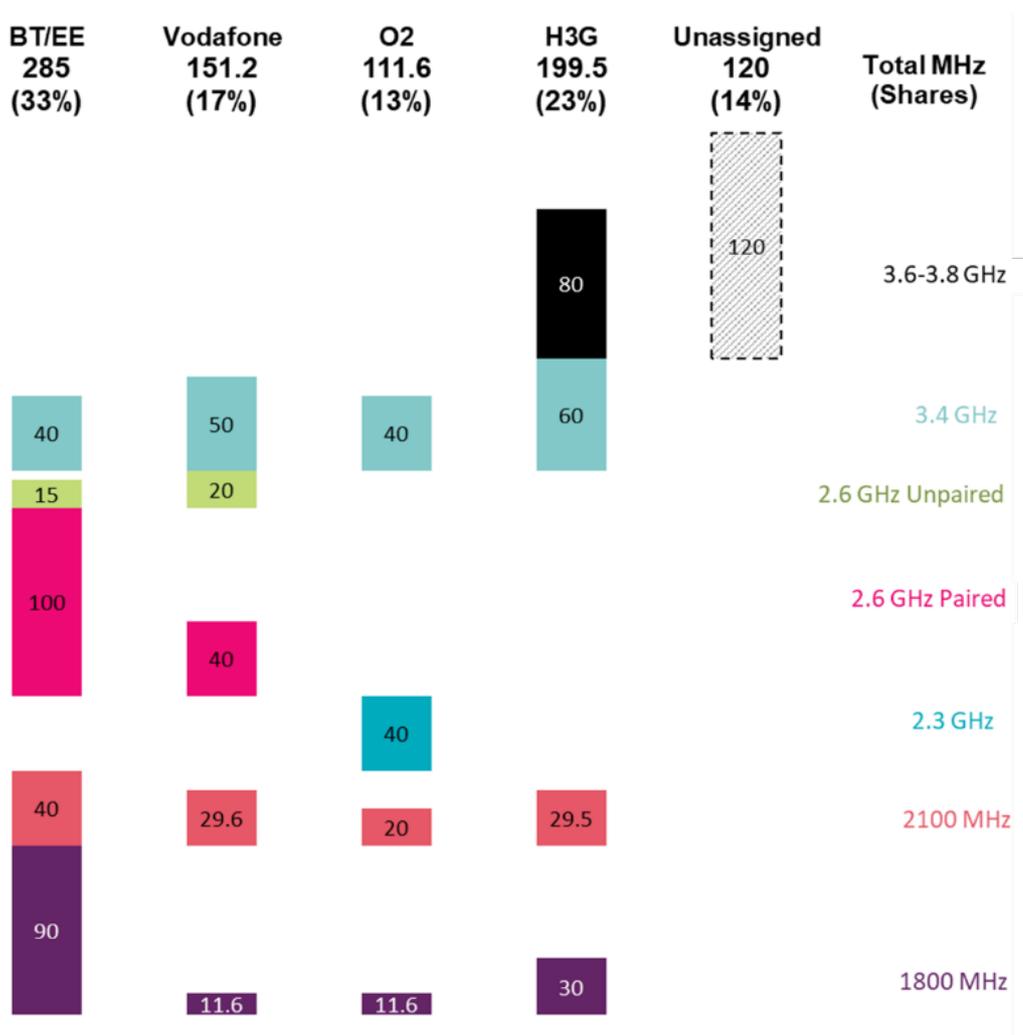
- 5.148 Our concerns relating to capacity spectrum are similar to those of concern 2a on overall spectrum asymmetry. Specifically, we would be concerned about a weakening of competition as a result of an MNO having a very large share of capacity spectrum. In theory, one of more of the following might occur:
- a) The ability of this MNO to add capacity more easily than its competitors may give it an unmatched competitive advantage.
 - b) Spectrum hoarding: an MNO with an already large share of capacity spectrum may not immediately deploy the spectrum, denying it to another MNO that would have deployed it quickly and use it to compete more strongly.
 - c) Excessive capacity spectrum could distort the market, allowing the MNO with a large share of this spectrum to raise prices for some services, easily respond to price decreases by competitors or to it becoming the only viable alternative for MVNOs, therefore reducing competition in the wholesale market.
- 5.149 We would also be concerned that competition might be weaker if one MNO had a relatively **low** share of capacity spectrum as it would have a higher marginal cost and more difficulty adding capacity, affecting how it competed in the market.
- 5.150 We do not believe that there is a specific **credibility** concern relating to capacity as all MNOs in the UK will have at least 13% of mid frequency spectrum and 14% of downlink spectrum, even if they do not win any additional spectrum in this award.
- 5.151 At a high level, there are two ways that we might assess the potential for asymmetries in 'capacity' spectrum: by considering mid frequency holdings, or by assessing downlink capacity. We consider each of these in turn.

Asymmetry in mid frequency spectrum

- 5.152 In general, using more spectrum provides additional capacity. As explained above, however, higher frequency spectrum has certain advantages in providing additional capacity, e.g. certain technologies such as massive MIMO are only likely to be available and practically deployable at higher frequencies.
- 5.153 Asymmetries in spectrum better suited to adding capacity may therefore raise potential competition concerns. However, it is difficult to measure the scale of any advantages offered by mid frequency spectrum, not least because some of the relevant technologies are still being developed while others are in the early stages of roll-out: making real world performance difficult to estimate.
- 5.154 In addition, *low frequency* spectrum may be more spectrally efficient in certain circumstances, for example in hard to serve areas such as indoors where its propagation characteristics are more favourable, as explained later in this section (see discussion of concern 2d). Determining the weighting to attach to individual spectrum bands would therefore require a high degree of regulatory judgement.

5.155 For illustrative purposes, we include below a particular case, namely where we only assess the level of asymmetry in mid frequency spectrum (i.e. spectrum above 1800 MHz and below 6 GHz). This is equivalent to saying that only mid frequency spectrum can be used to add capacity and all mid frequency bands are equally efficient in adding capacity, with low frequency spectrum providing no capacity at all.

Figure 5.4: Holdings and shares of mid frequency spectrum



5.156 Shares of mid frequency spectrum are similar to the shares of overall spectrum (as presented in Period D in Figure 5.3), although BT/EE has a higher share of mid frequency spectrum than overall spectrum (because it has very little low frequency spectrum).

5.157 Looking at these mid frequency holdings only, O2 would have the lowest share of this spectrum with 13%, if it won none in the award. BT/EE could have up to 47% of all the mid frequency spectrum if it won all the 3.6-3.8 GHz spectrum in this award (its 33% share plus the 14% share of unassigned spectrum). H3G could get to around 37% of mid frequency spectrum if it bought all of the 3.6-3.8 GHz in the award and Vodafone to 31%.

- 5.158 We might, therefore, be concerned if BT/EE bought most or all of the mid frequency spectrum in the award, that is the entire 120 MHz of 3.6-3.8 GHz. We might also be concerned if O2 bought none of the mid frequency spectrum.
- 5.159 As noted, if H3G bought all of the 3.6-3.8 GHz spectrum, it would have 37% of mid frequency spectrum, which is not above the level at which we have concerns for overall spectrum. We would not be concerned about this from a capacity perspective either (we consider potential concerns related to asymmetry in 5G spectrum below.)
- 5.160 Given Vodafone's 17% share of mid frequency spectrum, we think it is unlikely that it would end up with either a particularly high or low share of this type of spectrum.
- 5.161 However, assessing mid frequency spectrum holdings only does not present a realistic picture of potential asymmetries in the ability to add capacity as it disregards the fact that *low frequency* spectrum is also capable of adding capacity.
- 5.162 It also ignores the differences between the different mid frequency bands, as not all mid frequency bands will see the same performance boost from technologies such as massive MIMO and beamforming.¹¹¹ Thus the actual potential for the auction to introduce asymmetries in the ability to add capacity is likely to be significantly lower than suggested by Figure 5.4 above.
- 5.163 To investigate this further, we have carried out some high-level scenario analysis of capacity asymmetry levels using different notional weightings and found that the resulting asymmetry levels are not significantly different from overall spectrum asymmetry levels, unless the differences in weights are very large (i.e. several multiples of each other).¹¹²
- 5.164 Whilst it is possible the differences in spectral efficiency may be large, we nonetheless consider it likely that any capacity asymmetry will be broadly similar to overall spectrum asymmetry and that any extreme asymmetries will therefore be addressed by our proposed cap on overall spectrum.

Asymmetry in downlink capacity

- 5.165 Another way to measure capacity spectrum asymmetry is to only consider downlink capacity. The reason for measuring capacity spectrum in this way is that, nowadays, mobile networks carry mostly data and most of this traffic is generated by users downloading

¹¹¹ For example, for a given antenna panel size, the number of individual antenna elements (within the panel) for 1800 MHz and 2.1 GHz will be less than for 2.6 GHz and 3.4-3.8 GHz. This means that massive MIMO and beamforming will offer less of a performance increase for 1800 MHz and 2.1 GHz than for 2.6GHz and 3.4-3.8 GHz. Furthermore, these technologies such as Massive MIMO and beamforming are better suited to boost capacity under certain conditions, for example, for densely populated areas where spectrum can also be reused vertically as well as horizontally. This approach also fails to capture the potential advantages of TDD spectrum vs. FDD spectrum.

¹¹² For example, if all mid frequency spectrum is assumed to be twice as capable of providing capacity as low frequency spectrum, BT/EE's share of capacity would be 29.2%, compared to 26.4% for overall spectrum share, while O2's would be 14% for capacity vs. 14.9% for overall spectrum shares when all 700 MHz and 3.6-3.8 GHz spectrum is included in the relevant pool (the pool would therefore include some unassigned spectrum). In an extreme example, if all mid frequency spectrum were to be assumed have four times the spectral efficiency of low frequency spectrum, O2's capacity share would be 13.5% and BT/EE's would be 30.9%.

content. SDL and TDD are particularly advantageous for this traffic pattern as they allow for more capacity to be allocated to downlink.

5.166 If we only take into account downlink capacity, we obtain the following shares:

Figure 5.5: Holdings and shares of ‘downlink spectrum’

	BT/EE	Vodafone	O2	H3G	Unallocated
Holdings of downlink spectrum (MHz)	161	141	103	160	140
Shares of downlink spectrum	22.9%	19.9%	14.6%	22.7%	19.9%

5.167 In calculating our illustrative shares of downlink capacity, we have included 100% of the 700 MHz downlink-only and 1400 MHz downlink-only spectrum; 50% of all paired FDD spectrum; and 75% of TDD spectrum.¹¹³ Therefore, in awarding the 200 MHz in this auction, we are awarding the equivalent of 140 MHz of downlink spectrum:

- 30 MHz from the paired 700 MHz (50% of 60 MHz);
- 20 MHz of downlink-only 700 MHz; and
- 90 MHz from the 3.6-3.8 GHz (75% of 120 MHz).

5.168 Looking at the shares above, we might be concerned if downlink capacity were of significant importance and BT/EE, H3G or Vodafone acquired most or all of the spectrum in this award as this would bring their shares of downlink capacity over 37%. However, as discussed below, it is not clear that the thresholds for capacity spectrum asymmetry would be the same as those for overall spectrum asymmetry.

Step 2 – Severity of the effect on competition

5.169 Significant asymmetry in holdings of ‘capacity spectrum’ could have a material impact on competition in the market. An MNO with a very large share of ‘capacity spectrum’ could have an unmatched competitive advantage, especially for services that:

- a) require high throughput rates (i.e. high data rates in Mbps/s) and service consistency and reliability; and
- b) if the user is in an area where demand is close to capacity; and
- c) at times of the day when the network is close to capacity.

¹¹³ Based on an assumption of a 3:1 downlink-uplink ratio for TDD.

- 5.170 On the other hand, an MNO with a low share of capacity spectrum would be unable to add capacity at the same pace as its competitors and may compete less actively in certain segments of the market (e.g. high-consumption services in high density areas).
- 5.171 We might therefore be concerned about severe asymmetries in ‘capacity spectrum’, as with overall spectrum. Nonetheless, we do not consider that these are likely to arise (beyond any potential concerns for overall spectrum) and will be prevented by our proposed cap on overall spectrum.

Step 3 – Likelihood of outcomes which might cause concern

Asymmetries in mid frequency spectrum

Likelihood that BT/EE will gain an unmatched capacity advantage in mid frequency spectrum

- 5.172 If the capacity gains from the new technologies described above were significant (i.e. if the spectral efficiency of all mid frequency spectrum were several multiples of that of low frequency spectrum), we may be concerned if BT/EE acquired a significant share of the 3.6-3.8 GHz spectrum being auctioned.
- 5.173 Considering shares of mid frequency spectrum only, BT/EE could gain a share of 47% if it bought all of the 3.6-3.8 GHz. A capacity share of 47% would be above the level at which we would be likely to have concerns about the effect on competition. However:
- a) As noted above, we do not necessarily consider that shares of mid frequency spectrum alone represent a meaningful share of effective capacity;
 - b) It is not clear that the thresholds for capacity spectrum asymmetry would be the same as those for overall spectrum asymmetry;
 - c) Our proposed overall cap would prevent BT/EE from acquiring more than 37% of overall spectrum. As a result, BT/EE would be unlikely to acquire too much mid frequency spectrum.
- 5.174 On point (a), we note that this is particularly sensitive to the assumptions we make about the weighting of different bands of spectrum. If, for example, we counted low frequency spectrum as providing half as much capacity as mid frequency (rather than zero), then the maximum ‘capacity’ share that BT/EE could obtain would be 41%, assuming it bought all of the 3.6-3.8 GHz.
- 5.175 On point (c), we consider it unlikely BT/EE would buy all of the 3.6–3.8 GHz spectrum being awarded. From an intrinsic valuation perspective, given its existing holdings in mid frequency spectrum, it is difficult to see why BT/EE would have a higher valuation for all the spectrum in the 3.6-3.8 GHz band than the valuation of all other MNOs for part of the band.
- 5.176 We consider this likely to be reinforced by the fact that the overall cap would require BT/EE to trade off acquisitions in 3.6-3.8 GHz with spectrum in 700 MHz. Given BT/EE’s low holdings of low frequency spectrum, it is likely that it has a high intrinsic value for some spectrum in the 700 MHz band.

- 5.177 Having a diverse portfolio of spectrum can be advantageous as different bands have different properties. While spectrum that is particularly good for capacity may be valuable, low frequency spectrum is particularly good at wide-area coverage and in building penetration, as we will discuss in relation to concern 2d below. This contributes towards overall user perception of the ‘reliability’ of a mobile network.
- 5.178 In any event, if having a certain amount of ‘capacity spectrum’ is deemed to be necessary or advantageous, then it is to be expected that MNOs with a low share of this spectrum – O2 in particular – would have a higher intrinsic value compared to those that already have extensive holdings of this type of spectrum.

Likelihood that H3G will gain an unmatched capacity advantage in mid frequency spectrum

- 5.179 We consider it unlikely H3G would gain an unmatched advantage in relation to capacity spectrum, even if it were to acquire all of the 3.6–3.8 GHz being awarded. This outcome would bring its share to 37% of mid frequency spectrum. As noted above, it is not clear what the relevant thresholds should be for mid frequency spectrum alone but we would not expect to have concerns at this level.
- 5.180 H3G would only be able to attain a very high share of capacity spectrum if technological developments meant there were specific and unmatched capacity advantages to the band in the future, such that spectrum holdings in this band become significantly more useful for adding capacity than other spectrum bands, including other mid frequency bands.
- 5.181 We consider this unlikely as a mobile provider will need a varied spectrum portfolio to provide mobile services to customers in different environments (e.g. rural, indoor and other locations, such as roads), given the less favourable propagation characteristics of the 3.4–3.8 GHz band - and given it is unlikely that new technologies will significantly increase the propagation range when using these frequencies.¹¹⁴
- 5.182 In addition, we consider that H3G is unlikely to acquire all of the 3.6-3.8 GHz in this award. Given its existing large holdings in this band, it is likely to have a lower intrinsic value for it than all other bidders.
- 5.183 Thus we do not consider there are any competition concerns in relation to H3G acquiring an asymmetric share of capacity spectrum.

Likelihood that O2 will end up with a very low share of mid frequency spectrum

- 5.184 If O2 failed to acquire any mid frequency spectrum, it could end up with a higher marginal cost of adding capacity than other operators. We do not consider that the concerns for O2 in terms of mid frequency or ‘capacity’ spectrum are particularly different from those in our consideration of O2’s position in terms of overall spectrum holdings as it has low

¹¹⁴ Studies from vendors suggest that 3.4 – 3.8 GHz base stations using massive MIMO may be able to match the coverage of 1.8 and 2.1 GHz base stations but will not match the coverage provided by base stations using 1.4 GHz or below. Similarly, uplink-downlink decoupling is only likely to provide a modest increase in the range of 3.4 – 3.8 GHz base stations and requires a lower frequency band for the uplink component.

frequency and mid frequency spectrum (including the 3.4 GHz it won in the recent auction).

- 5.185 As noted above, our proposed cap does not guarantee that O2 will win spectrum in the award, but it would make it more likely by limiting the amount that BT/EE could acquire. We do not therefore consider that additional measures (e.g. spectrum reservations in mid frequency spectrum) are required in addition to our proposed overall cap.
- 5.186 If mid frequency spectrum in particular were deemed to be very important to compete, then O2 (with less of it) would be likely to have a high intrinsic value for it. One way in which O2 might fail to win mid frequency spectrum is if the other MNOs individually or collectively engaged in strategic bidding to prevent O2 from acquiring it – that is, they bid above their own intrinsic value for it in order to deny it to O2.
- 5.187 We consider incentives for strategic bidding in relation to capacity spectrum are weak as it is not clear what the other MNOs would achieve by foreclosing O2 (or indeed any MNO) from the 3.6-3.8 GHz band.
- 5.188 Strategic bidding to prevent O2 from acquiring any of the auctioned mid frequency spectrum (i.e. 3.6-3.8 GHz) is unlikely to threaten its ability to compete. For example, using the illustrative shares of capacity spectrum above, O2 would still hold 13% of the mid frequency spectrum, including 40 MHz of 2.3 GHz and 40 MHz of 3.4 GHz spectrum, both of which are TDD bands. It would also hold almost 15% of the downlink spectrum, as outlined below.
- 5.189 The fact that O2 now has 112 MHz of mid frequency spectrum (including 40 MHz in 3.4-3.6 GHz), compared to only 32 MHz before the 2018 auction, means that it will also benefit from any increases in spectral efficiency of mid frequency bands. In addition, any 700 MHz that O2 acquires as well as its current low frequency spectrum holdings would also boost its capacity, even if not as effectively as 3.6-3.8 GHz.
- 5.190 As we discuss in the context of concern 2c (below), no MNO is able to block the path to 5G for any other MNO by preventing them from buying 3.6-3.8 GHz spectrum. We consider that the current holdings of all MNOs are sufficient for them to have a long-term path to 5G, even if they do not win any spectrum in this auction.
- 5.191 We acknowledge below that there could be advantages, mainly in the shorter term, in having larger blocks of 3.4-3.8 GHz spectrum. But, as discussed above, in paragraphs 5.54 to 5.60, strategic investments of this nature (to deny rivals larger blocks of 3.4-3.8 GHz spectrum) are unlikely to be profitable and, in the case of coordinated strategic bidding, difficult to achieve.

Asymmetries in downlink spectrum

- 5.192 We might be concerned if BT/EE acquired all or almost all of the downlink capacity we are auctioning, as its share of downlink would reach 42% (as set out in Figure 5.5 above).
- 5.193 However, it is not possible for BT/EE to acquire this much spectrum under the terms of our proposed overall cap, which would restrict BT/EE to acquiring a maximum of 120 MHz. The

maximum downlink capacity that BT/EE could buy, therefore, is 95 MHz,¹¹⁵ or just over 13% of all downlink spectrum. This would take BT/EE's share of downlink spectrum to 36.4%.

- 5.194 However, we consider that even this outcome is highly unlikely as it would not allow BT/EE to acquire any 700 MHz paired spectrum, which it is likely to value as it currently has very little low frequency spectrum. We do not consider that BT/EE, or indeed any MNO, is likely to base its bidding in the auction principally on which spectrum gives it the most downlink capacity. It is likely to consider other properties of the spectrum available and aim to obtain a balanced portfolio.
- 5.195 If H3G bought as much spectrum as it could, and focused on downlink, it could acquire an additional 130 MHz, or 18%, of downlink capacity.¹¹⁶ H3G could, therefore, in theory get to 41% of downlink capacity.
- 5.196 However, we consider it unlikely that H3G would buy all of the 3.6-3.8 GHz spectrum for the reasons set out above.
- 5.197 Under our proposed cap, Vodafone could buy an additional 135 MHz of downlink capacity. This would take its share to 39%. This would involve Vodafone buying all of the 3.6-3.8 GHz band, all of the 700 MHz downlink-only spectrum and 50 MHz of the 700 MHz paired spectrum. We consider it is unlikely its intrinsic valuation for all of this spectrum is greater than other operators' valuation for part of this spectrum.
- 5.198 It is possible, therefore, that H3G or Vodafone could get a share of downlink spectrum above 37% if either of them bought all of the 700 MHz downlink-only, all of the 3.6-3.8 GHz and a large portion of the 700 MHz paired spectrum. Nonetheless, we do not consider that there is a competition concern because:
- a) it is unlikely that Vodafone or H3G's intrinsic values for all of this spectrum would exceed other MNOs' valuations for at least some of it.
 - b) we consider incentives for strategic bidding in relation to downlink capacity are weak as it is not clear what such behaviour would achieve.
 - c) it is not clear whether 37% is the relevant threshold for a concern in downlink spectrum alone.
- 5.199 Moreover, even if one of these outcomes were to pertain, it would not result in significantly greater asymmetry in downlink spectrum than in overall spectrum holdings. Both Vodafone and H3G would have shares of overall spectrum below 37% and it is unlikely that having a slightly higher share of downlink-only spectrum would translate into an unmatchable competitive advantage for either operator.

¹¹⁵ To maximise the downlink capacity it bought, given the constraint of the overall cap, BT/EE would need to buy the 20 MHz of 700 MHz downlink-only and 100 MHz of the 3.6-3.8 MHz. For downlink capacity, we count all 20 MHz of the 700 MHz downlink-only and 75% of the 100 MHz of 3.6-3.8 GHz.

¹¹⁶ H3G could acquire 185 MHz of overall spectrum under the proposed cap. It could therefore buy 20 MHz of 700 MHz downlink-only, 120 MHz of 3.6-3.8 GHz and 40 MHz of paired 700 MHz spectrum to maximise its acquisition of downlink spectrum.

- 5.200 We thus consider any concerns about extreme asymmetry in downlink spectrum to be addressed by the overall cap.

Steps 4 and 5 – Relevant competition concerns and competition measures

- 5.201 As outlined above, we do not think there are specific concerns relating to capacity spectrum that have not been addressed through the assessment of asymmetry in overall spectrum shares (concern 2a).
- 5.202 As there are no relevant competition concerns we do not propose any competition measures relating to capacity spectrum.

Competition concern 2c: asymmetry and credibility related to ‘spectrum that can be used for 5G’

Introduction and summary

- 5.203 We now consider whether there are any specific competition concerns relating to our award of 120 MHz of spectrum in the 3.6-3.8 GHz band, which is part of the wider 3.4-3.8 GHz band. Given that this may be an important band for 5G, we need to assess this in the context of the wider pool of 5G spectrum i.e. spectrum that can be used to deploy 5G and that will be capable of providing a wide range of 5G services.

What spectrum bands will be used for 5G?

- 5.204 What constitutes ‘5G spectrum’ will change over time depending on which bands are enabled for 5G use and are available in handsets. As we describe below, we expect that 5G spectrum may initially involve the 3.4-3.8 GHz band but should grow over time to encompass the majority of existing UK mobile bands.
- 5.205 It is worth recalling that 4G was not launched on the 800 MHz and 2.6 GHz bands (auctioned in 2013) which were expected to be used for 4G, but rather on the 1800 MHz band. Other legacy 2G and 3G bands are currently being re-purposed for 4G.¹¹⁷ Therefore it may difficult at this stage to be certain about which bands will be key to the deployment of 5G.
- 5.206 Press reports from MNOs indicate that they will use their current holdings in 3.4-3.6 GHz for initial 5G deployments with some limited roll-out having started in 2018 and commercial launches from some operators starting from as early as 2019.¹¹⁸

¹¹⁷ For example, BT/EE has recently announced that it will re-farm all of its existing 3G bands into 4G. See <https://www.ispreview.co.uk/index.php/2018/09/ee-re-farms-uk-3g-spectrum-into-ultrafast-4g-mobile-broadband-bands.html>

¹¹⁸ BT/EE has already announced plans to launch 5G services using their 3.4 GHz spectrum as early as 2019 – see <https://www.ispreview.co.uk/index.php/2018/05/bt-and-ee-aiming-to-uk-launch-commercial-5g-mobile-in-2019.html>

- 5.207 700 MHz spectrum may be a useful band for providing 5G coverage¹¹⁹ in the future especially outside densely populated areas, while the wider 3.4-3.8 GHz band has been singled out as a particularly useful band for 5G given the possibility of MNOs being able to deploy large bandwidths using TDD spectrum – providing a good balance in terms of capacity (i.e. throughput rates) and the ability to deploy it on existing sites.
- 5.208 mmWave bands such as 26 GHz have also been identified as 5G bands. These bands are likely to play an important role in the future of 5G, for example for targeted deployments of small cells to support the delivery of services that require very high throughput rates and very low latency.
- 5.209 As we explain in annex 8, UK MNOs already have holdings in mmWave bands, including regional licences held by H3G, O2 and Vodafone in the 28 GHz band, which is also expected to be deployed in the US for FWA services. However, there is still some uncertainty about how this spectrum will be deployed given that its propagation characteristics are very different to that of current mobile bands.
- 5.210 Over time we expect that many, if not all, of the existing UK mobile bands will also be enabled for 5G use. 5G NR Release 15 v2, which was finalised in June 2018, includes the specifications for almost all of the UK mobile bands, meaning that it will be technically feasible to develop the necessary technologies to use these bands with 5G NR.¹²⁰
- 5.211 In addition, 5G technologies such as massive MIMO and beamforming – which will be responsible for most of the capacity boost required by 5G services – can be deployed with LTE Advanced Pro (the latest evolution of 4G LTE).¹²¹ In annex 7, we describe the technical standard evolutions for LTE, noting that LTE Advanced Pro supports many of the same early technology advances and use cases as 5G NR.
- 5.212 The speed at which existing bands will be enabled for 5G use will depend to a large extent on requests from MNOs to chipset makers and device manufacturers to include support in upcoming devices. As these bands are enabled, mobile operators will be able to use existing spectrum for 5G, much like all legacy 2G and 3G bands can now be re-farmed for 4G use.
- 5.213 Hence, while initial deployments of 5G may use the bands that have initially been identified as 5G bands (i.e. 3.4-3.8 GHz), subject to the 5G device ecosystem availability,

¹¹⁹ In our 5G document (https://www.ofcom.org.uk/data/assets/pdf_file/0021/97023/5G-update-08022017.pdf), we identified 700 MHz as a band that, if deployed on existing sites, would provide a similar level of 5G coverage as current 4G networks.

¹²⁰ See http://niviuk.free.fr/nr_band.php. All current and future UK Mobile bands below 3.8 GHz were included in Release 15, with the exception of 700 MHz downlink-only (for SDL). Any additional bands may be supported in future releases, e.g. release 16 which is expected by the end of 2020. It is worth bearing in mind that initial 4G releases did not include the technical specifications for existing 2G/3G bands. Therefore, it is feasible that specifications for 5G NR in existing bands will be developed at a quicker pace than was the case for 4G LTE.

¹²¹ See, for example, Telefonica's recent announcement of massive MIMO deployment in London Kings Cross and Marble Arch areas on their 2.3 GHz spectrum currently used for LTE, <https://news.o2.co.uk/press-release/o2-launches-pilot-to-boost-london-network-ahead-of-5g/>

other bands should see 5G deployments over time as the required technology is developed.

What might 5G services look like?

- 5.214 There are two dimensions to 5G: improvements in network performance and 5G-specific services. We expect that initial 5G deployments in the early 5G spectrum bands (i.e. 700 MHz and 3.4-3.8 GHz) will enable improved services such as enhanced mobile broadband (eMBB) – i.e. better network performance – with wider 5G-specific services using a larger pool of 5G spectrum bands being launched at a later date.
- 5.215 There is no specified minimum bandwidth requirement to offer a 5G service, e.g. 5G NR can be deployed on single carriers as narrow as 5 or 10 MHz up to 100 MHz.¹²² However, industry stakeholders have indicated that it would be desirable to deploy 5G on carriers of 80 to 100 MHz to deliver the capability that the IMT 2020 vision envisages for eMBB. Given the relatively low amount of low frequency spectrum available, compared to mid frequency, MNOs will likely only achieve these wide bandwidths with mid or high frequency (i.e. mmWave) spectrum.
- 5.216 Some operators may also start using spectrum in the 3.4-3.8 GHz band (as well as in other bands) for Fixed Wireless Access (FWA). In the UK, BT/EE already offers the FWA service ‘4GEE’, and H3G is expected to offer home broadband using 5G technology to grow its existing Relish business.^{123,124}
- 5.217 Demand for FWA services may grow as the widespread roll-out of such technologies leads to service offerings which consumers find to be closer substitutes for services provided over fixed access connections than the FWA services currently available. As demand for FWA services is still limited, and they can be offered on spectrum bands other than 3.4-3.8 GHz, we do not consider there are specific competition concerns for these services.
- 5.218 The nature of 5G services is currently uncertain, since no 5G services are yet being offered, and 5G may initially simply represent an improvement to existing network performance. We discuss 5G services in annex 7 where we group the types of services and applications 5G is likely to support into three broad categories or usage scenarios: enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable low-latency communications (uRLLC).
- 5.219 We do not know how 5G services will develop and the importance they will have for the market and consumers in the future. Although we do not believe that an MNO will need to be able to offer all of the above 5G services to remain credible in the short term, if it could not deliver services that would allow it to compete in this dimension in the long term, its

¹²² Note that 5 MHz carriers are not specified for 5G NR in the 3.4-3.8 GHz band, but they are for frequency bands below 3 GHz. The maximum bandwidth for 5G NR carriers in FDD bands below 3 GHz is 20 MHz.

¹²³ Trade name for UK Broadband.

¹²⁴ In partnership with SSE, H3G has already deployed a new fibre network reaching 20 data centres, it has deployed a new 5G core network and carrier aggregation and MIMO technologies in the access to add capacity to the existing mobile and home broadband networks. <http://www.threemediacentre.co.uk/news/2018/three-UK-committed-to-invest-into-5g.aspx>
<https://www.lightreading.com/mobile/5g/three-uk-to-go-big-on-5g-for-home-broadband/d/d-id/747490>

credibility would be threatened and competition in the UK mobile market may be weakened.

What spectrum will be required to offer 5G?

- 5.220 The MNOs have indicated that it is desirable to have 80 to 100 MHz to offer the 5G services described above. If this is the case, we believe that at present all MNOs have a long-term route to offer a wide range of 5G services even if they fail to acquire any spectrum in this auction. We recognise that O2's path may be slightly more difficult and costly given its lower existing holdings of mid frequency spectrum. However, we do not believe there is a long-term threat to O2's credibility from insufficient suitable spectrum.
- 5.221 Wide-coverage 5G networks are likely to be based on some low frequency spectrum in the same way that low frequency spectrum is currently used to provide coverage for 4G services.
- 5.222 This auction could introduce significant asymmetries in spectrum that is particularly well suited to 5G. For example, if H3G acquired all the 3.6-3.8 GHz spectrum available in the auction it would hold more than 65% of the 3.4-3.8 GHz band. However, it is highly unlikely that H3G would win large amounts of 3.6-3.8 GHz because it is likely to have a lower intrinsic value for this spectrum than the other MNOs: it already holds 140 MHz in the 3.4-3.8 GHz band, whereas the others have 40 or 50 MHz.
- 5.223 In any case, we do not think that an operator with a large holding of 3.4-3.8 GHz would gain an unmatched advantage in the market. Furthermore, we are not aware of evidence of different tiers of 5G services that can only be provided with specific spectrum portfolios. More spectrum should allow an MNO to provide a better quality of service, but such asymmetries are covered in the context of concerns 2a, 2b and 2d. Therefore, we do not believe that there is a specific 5G spectrum asymmetry concern.

Step 1 - Which outcomes raise concerns?

We consider that, to remain credible, an MNO needs to be able to offer 5G services that will matter to consumers in the future

- 5.224 The current expectation is that, in the short-term (i.e. 2019-2020), 5G deployments will focus on enhanced mobile broadband (eMBB) and will rely on legacy LTE core networks. 5G-specific services built on a 5G core network are likely to be available later.¹²⁵
- 5.225 Evidence suggests that existing 4G deployments have the potential to take advantage of many of the same technical advances as 5G. In that case there may only be a relatively small performance difference between upgraded 4G and early 5G deployments.¹²⁶ Furthermore, 4G technology is expected to continue to evolve for a few more years.

¹²⁵ We distinguish between the short-term (i.e. being able to deploy 5G services as soon as – or shortly after – 5G technology is available) and long-term (i.e. within five to ten years after the technology is first deployed).

¹²⁶ Active antenna arrays and other recent improvements in spectral efficiency will be available in the latest releases of 4G as well as 5G.

- 5.226 5G will, however, provide additional capacity, making MNOs' networks more efficient and able to meet the increasing consumer demand for mobile data effectively. Initial 5G services other than eMBB are likely to be more focused on industrial or business applications and, therefore unlikely to be important for all (or even most) consumers immediately. Therefore, we do not believe MNOs will cease to be credible in the short-term if they are unable to offer these new services.
- 5.227 It is more difficult to predict what new services consumers will value in the longer term, and whether these new services will decisively affect the nature of competition in the market.
- 5.228 Certain 5G applications are under development and trial now, with commercial launch expected in 2019,¹²⁷ but these remain oriented to industrial and business applications: for example, applications that rely on the high reliability and low latency offered by 5G. Consumers may also start valuing applications that require higher speeds and lower latency, such as virtual/augmented reality or higher definition video streaming.
- 5.229 Notwithstanding any uncertainty over the spectrum necessary to provide 5G services, we consider it important that each MNO has a long-term route to offer innovative and more demanding services if these matter to consumers in the future (i.e. within next 5 to 10 years). An MNO might not remain credible if it were unable to offer such services in a timely and cost-effective manner and, therefore, competition might be weakened.

All MNOs have a long-term route to be able to offer a wide range of 5G services with existing spectrum holdings

- 5.230 In order to offer the wide range of services that 5G technology is capable of supporting, MNOs will require a portfolio of spectrum (including some low frequency spectrum).¹²⁸ It has been argued that they will need large bandwidths of mid frequency spectrum, together with the deployment of a 5G radio access network and a 5G core network. However, as we discussed in the introduction to this section, we expect that the vast majority of spectrum bands will eventually be supported for 5G, even if only a subset of the bands currently useable for mobile can be used for 5G in the short-run.
- 5.231 We would be concerned about a potential outcome of the auction that would not allow an MNO to build the spectrum portfolio that it would need to be able to offer 5G services that will allow it to compete in this dimension in the long run.
- 5.232 However, all MNOs currently have some low frequency spectrum as well as at least 80 MHz of mid frequency spectrum. They therefore all have a long-term path that will allow them to offer a wide range of 5G services, even if they fail to acquire any spectrum in this auction, as outlined in the table below.

¹²⁷ R16 is due to be frozen in December 2019, and commercial deployments are therefore expected in 2021.

¹²⁸ We do not expect 5G NR deployed in low frequency spectrum, including 700 MHz, to provide significant capacity improvements over LTE in these frequencies, at least in the short to medium term. However, low frequency spectrum will be important to provide reliability to many 5G services, launched in the longer term, requiring ultra-low latency as well as massive machine-to-machine communications in areas where it is hard to provide coverage.

Figure 5.6: The long-term route to 5G for each operator

Operator	Spectrum for early 5G deployments?	Spectrum for long-term route to offer wide range of 5G services? ¹²⁹	Observations
BT/EE	Yes – 40 MHz of 3.4 GHz	Yes – 245 MHz of additional mid frequency spectrum in the 1800 MHz 2.1 GHz and 2.6 GHz bands as well as 10 MHz of low frequency spectrum in 800 MHz	<p>Given its large 1800 MHz and 2.6 GHz spectrum holdings, it should be able to migrate some of its existing holdings relatively easily in order to be able to offer 5G services.</p> <p>It may also need to migrate its existing 10 MHz of 800 MHz, which may be more difficult than for those with larger low frequency spectrum holdings. However, BT/EE's coverage network was largely developed based on mid frequency spectrum (i.e. 1800 MHz) so it could also migrate mid frequency spectrum to offer coverage.</p>
H3G	Yes – 60 MHz of 3.4 GHz and 80 MHz of 3.6-3.8 GHz	Yes – at the very least will be able to use the 140 MHz it already holds in 3.4-3.8 GHz and its 10 MHz of 800 MHz spectrum.	Does not depend on LTE bands being enabled for 5G to be able to offer a wide range of 5G services given its holdings in 3.6-3.8 GHz, though it may need to migrate its 10 MHz of 800 MHz in order to provide certain 5G services (especially those requiring wide area coverage), which may be more difficult than for those with larger low frequency spectrum holdings.

¹²⁹ Assuming that long-term 5G services will require MNOs to hold at least 80 MHz of mid frequency spectrum.

Operator	Spectrum for early 5G deployments?	Spectrum for long-term route to offer wide range of 5G services? ¹²⁹	Observations
O2	Yes – 40 MHz of 3.4 GHz	Yes – but will need to migrate a large part of its existing mid frequency spectrum. It also holds 55 MHz of low frequency spectrum in 800 MHz and 900 MHz.	Has potentially a slightly more difficult long-term path. Relatively small mid frequency holdings mean that migrating these to 5G might be a more complex process than for other MNOs with larger mid frequency holdings. On the other hand, it has an easier path to migrate some of its low frequency spectrum in order to deploy a 5G coverage network.
Vodafone	Yes – 50 MHz of 3.4 GHz	Yes – 101 MHz of additional mid frequency spectrum in the 1800 MHz, 2.1 GHz and 2.6 GHz bands and 75 MHz of low frequency spectrum in the 800 MHz, 900 MHz and 1400 MHz bands	Has the second largest current holding of 3.4-3.8 GHz and should be able to use other spectrum from its existing mid frequency portfolio, such as 2.6 GHz. It also has an easier path to re-farm some of its low frequency spectrum in order to deploy a 5G coverage network.

5.233 Therefore, we do not believe that there is a long-term credibility concern. All MNOs have suitable spectrum for a clear path to be able to offer the wide range of 5G services in the future which will be important to consumers and competition even if they fail to acquire any spectrum in the current auction. Indeed, we note that all UK MNOs have announced the launch or trial of what they are branding as ‘5G’ services from next year, using their current spectrum holdings:

- BT/EE has announced plans to launch 5G in 16 cities in 2019, starting with London, Cardiff, Edinburgh, Belfast, Birmingham and Manchester.¹³⁰ BT/EE is currently trialling a number of 5G sites across East London.¹³¹
- In April 2018 Telefónica (O2) published a document on the benefits 5G deployment will bring to the UK,¹³² and in November launched a trial of Massive MIMO technology in

¹³⁰ <https://newsroom.ee.co.uk/ee-announces-5g-launch-locations-for-2019/>

¹³¹ <https://newsroom.ee.co.uk/ee-switches-on-5g-trial-sites-in-east-london/>

¹³² <https://d10wc7q7re41fz.cloudfront.net/wp-content/uploads/2018/03/Smart-Cities-Report.pdf>

London's Kings Cross and Marble Arch using its 2.3 GHz spectrum.¹³³ It has also announced plans to launch a 5G test bed at the O2 venue in London later this year.¹³⁴

- Vodafone has switched on a 5G trial in Salford, Greater Manchester,¹³⁵ with plans to commence 5G trials soon in a further six cities before the end of 2018.¹³⁶ In September, it used 5G technology to conduct a live holographic call. Vodafone has also outlined plans to have 1,000 5G sites by 2020.¹³⁷
- H3G continues its preparations for the roll-out of 5G with an enhanced agreement with SSE Enterprise Telecoms to connect H3G's network to hundreds of BT exchanges. It has rolled out carrier aggregation and MIMO technologies in the access network to add capacity to its existing mobile and home broadband networks. This follows an agreement signed with Nokia to build a fully virtualized 5G-ready core network¹³⁸ It has also announced plans to launch a 5G wireless home broadband service in the second half of 2019.¹³⁹

5.234 We acknowledge that O2's path to offering a wide range of 5G services may take slightly longer as some of their existing holdings (e.g. the recently acquired 40 MHz of 2.3 GHz) are being used for 4G. Nonetheless, we believe that, if its credibility depended on it doing so, O2 will be able to use its existing 3.4 GHz spectrum in aggregation with other spectrum bands, such as the 2.3 GHz, which are likely to be enabled for 5G.

5.235 We also acknowledge that BT/EE and H3G may have a more difficult path to migrate their existing low frequency spectrum in order to provide a 5G coverage network because they have low holdings of low frequency spectrum. Nonetheless, we believe they would be able to do so if their ability to compete in the market depended on it.

Asymmetry in 5G spectrum

5.236 Given H3G's large current holdings of 3.4-3.8 GHz (140 MHz), significant asymmetry in the band could arise if it acquired a large portion of the remaining 120 MHz in this auction. It could end up with around two thirds of the spectrum in the band.

¹³³ <https://news.o2.co.uk/press-release/o2-launches-pilot-to-boost-london-network-ahead-of-5g/>

¹³⁴ <https://news.o2.co.uk/press-release/o2-launch-5g-test-bed-o2/>

¹³⁵ <https://mediacentre.vodafone.co.uk/news/vodafone-first-full-5g-in-the-uk/>

¹³⁶ <https://mediacentre.vodafone.co.uk/pressrelease/5g-trial-seven-cities/>

¹³⁷ <https://mediacentre.vodafone.co.uk/news/vodafone-makes-uks-first-holographic-call-using-5g/>

¹³⁸ See footnote 124.

¹³⁹ <http://www.threemediacentre.co.uk/news/2018/5g-wireless-home-broadband-predicted-to-double-internet-speeds-for-uk-households.aspx>

Figure 5.7: Holdings and shares of 3.4-3.8 GHz spectrum

	BT/EE	Vodafone	O2	H3G	Unallocated
Holdings (MHz)	40	50	40	140	120
Shares of 3.4-3.8 GHz Spectrum	10%	13%	10%	36%	31%

5.237 Nonetheless, for this to be a concern there would need to be evidence that large holdings of this band would give an advantage that cannot be matched with holdings of any other band.

5.238 Some of the advantages of 3.4-3.8 GHz spectrum include:

- a) It will be one of the first 5G-enabled mobile bands.
- b) It is, for the most part, new mobile spectrum which does not need to be migrated from an older technology.
- c) It is TDD spectrum, which is potentially better suited to actual traffic patterns (i.e. asymmetric traffic patterns) than FDD spectrum, although synchronisation requirements create a trade-off between flexibility in the uplink/downlink ratios and spectral efficiency. We have already discussed TDD spectrum in the context of concern 2b.
- d) Larger bandwidths are available, which would allow for higher peak speeds and greater capacity.
- e) It is well suited for massive MIMO, which increases spectral efficiency, allowing for reasonably-sized antennas with a large number of elements.

5.239 However, none of these advantages suggest that an MNO with even a very large holding of this spectrum would have an unmatched competitive advantage over operators with smaller holdings. Specifically:

- 5G Release 15 v2 already includes support for most UK mobile bands and, therefore, the ecosystem for many of these should develop shortly after the ecosystem for 3.4-3.8 GHz, if not at the same time.
- BT/EE, Vodafone and O2 already have holdings in other TDD bands.¹⁴⁰ Further, the same upload/download capacity can be achieved with larger amounts of FDD spectrum and, therefore, an MNO with large amounts of mid frequency FDD spectrum should be able to match the performance of an MNO with large holdings of 3.4-3.8 GHz spectrum.

¹⁴⁰ BT/EE and Vodafone have 15 MHz and 20 MHz respectively in the 2.6 GHz unpaired band while O2 has 40 MHz in the 2.3 GHz band.

- Equivalent peak speeds can be achieved through carrier aggregation, even if an additional allowance must be made for guard bands and overheads.¹⁴¹
 - Other mid frequency bands are also well suited for massive MIMO.
- 5.240 If H3G were to acquire all of the 3.6-3.8 GHz spectrum, it is possible it could gain an initial advantage in providing 5G services. In particular, with significantly more capacity than other operators in a pioneer band for 5G, it is possible H3G could offer faster average speeds to its initial 5G customers.
- 5.241 H3G could make a generally much more efficient use of its network resources, e.g. it will be able to offer higher capacity in a timely and cost-efficient manner. However, this would be unlikely to give H3G an unmatched advantage over other operators when competing for customers, especially in the longer term.
- 5.242 In the first instance, it would not enable H3G to offer services which other operators could not also offer. As noted above, we are not aware of any 5G services requiring a specific amount of spectrum: all operators currently hold at least 40 MHz in the 3.4-3.8 GHz band and will be able to use spectrum from other bands once these become available for 5G use.
- 5.243 Having a very large share of this spectrum would also not allow H3G to bring 5G services to market any earlier than its rivals. Again, as noted above, all other operators have already announced trial and launch of 5G services next year.
- 5.244 It is also not clear that H3G would have any advantage in the provision of early 5G applications, even if it acquired all of the 3.6-3.8 GHz being awarded. This is because early 5G services are likely to depend on the availability of both LTE and 5G NR networks and other operators (particularly BT/EE) have LTE networks which perform better than H3G's in a number of dimensions, including coverage and capacity.
- 5.245 Even if H3G were initially able to offer a faster 5G service than other operators, most users would be unlikely to notice this difference in speed. This is because there would be no performance impact for the applications which are currently most valuable to consumers (e.g. browsing the internet).¹⁴² For example, Global Wireless Solutions¹⁴³ reports that the most important phone functions for UK adults are making calls (69%), texting (53%) and browsing the internet (43%).
- 5.246 Whilst it may be a driver for data traffic, only 3% of UK adults listed watching videos as a top priority. This evidence suggests that less data intensive services are currently more important to consumers. Higher 5G speeds are only likely to be noticeable when using data-intensive applications such as streaming HD videos (or possible future services that do not yet exist), rather than for the – currently more important – phone functions such as

¹⁴¹ Combined guard band and carrier aggregation signalling overheads might be in the range 2 – 15%. We discuss the inputs to this range in more detail in the next section.

¹⁴² See annex 6, paragraphs A6.124 to A6.130.

¹⁴³ <http://news.gwsolutions.com/2018/04/24/poor-signal-drives-half-a-million-millennials-to-throw-their-phones-in-anger/>

making calls, texting or browsing the internet. Also, as we noted above (see footnote 90), the fastest data speeds do not necessarily provide the best video experience.

- 5.247 Relatedly, we note that speed is not the only factor customers consider when choosing between providers, so having an advantage in this dimension would be unlikely to provide H3G with an unmatched advantage over other operators when competing for customers.
- 5.248 Some consumers may value other aspects of their service, such as price, customer service, handset choice, or contract terms. For example, research by Enders¹⁴⁴ (see annex 6, paragraph A6.106) shows that customers value price almost as much as ‘network quality’ when choosing a network. Customer service and handset range are also important.
- 5.249 Moreover, network quality is a broad concept, covering aspects such as reliability, coverage, download and upload speeds, latency, webpage browsing times, call quality and call success rates. In terms of what network quality means to customers, evidence suggests that data speeds are not the most important factor in choosing a provider. For example, Enders Analysis has shown that customers value reliability and coverage much more highly than data speeds (see annex 6, paragraph A6.106).
- 5.250 Similarly, Global Wireless Solutions found that when asked to consider the five most important factors for choosing a network, respondents were twice as likely to identify reliability than network speed (see annex 6, paragraph A6.109).
- 5.251 Demand for applications where differences in speed are more noticeable is likely to increase in the future (e.g. HD video streaming or future applications such as augmented or virtual reality), and speed may become a more important driver of competition as a result. However, the ecosystem for other spectrum bands is likely to be well-developed within this timescale such that operators with large holdings in other frequency bands will be able to match the speeds offered by H3G by deploying 5G services in these bands (to the extent that consumers do indeed value these higher speeds).
- 5.252 Moreover, other dimensions of competition are likely to remain important to consumers and MNOs’ capabilities must be considered in the round. Whilst H3G has a strong position already in relation to 3.4-3.8 GHz and would have a stronger position still if it acquired the 3.6-3.8 GHz being awarded, other operators have strengths in other dimensions. For example, H3G has relatively low holdings of low frequency spectrum (which is particularly useful for coverage) compared to other operators and (as shown in Figure 5.3, it only has 18% of currently allocated spectrum).
- 5.253 In summary, the evidence does not suggest that an MNO with large shares of 3.4-3.8 GHz spectrum would have materially superior capabilities compared to an MNO with similar amounts of spectrum in different mid frequency bands.¹⁴⁵ Whilst H3G currently has an advantage in relation to 3.4-3.8 GHz spectrum, other operators also hold large amounts of

¹⁴⁴ <http://www.endersanalysis.com/publications?date%5Bvalue%5D%5Bdate%5D=&title=covert+growth+in+mobile> published in 2018 based on 2017 survey.

¹⁴⁵ As shown in Figure 5.4, BT/EE, Vodafone and O2 have 285 MHz, 151.2 MHz and 111.6 MHz respectively of mid frequency spectrum.

mid frequency spectrum: thus it is unlikely H3G would gain a material advantage over other operators, even if it were to acquire all of the 3.6-3.8 GHz being awarded.

- 5.254 Therefore, we believe there are no specific concerns relating to asymmetry in the 3.4-3.8 GHz band.

Other potential concerns relating to spectrum contiguity and proximity of different 5G spectrum carriers

- 5.255 As already noted, industry stakeholders have indicated that, in their view, it is desirable to deploy 5G on carriers of 80 to 100 MHz to deliver the high-speed services envisaged for eMBB. The MNOs with holdings of 40 or 50 MHz in the 3.4-3.6 GHz band (BT/EE, O2 and Vodafone) are therefore likely to want to acquire additional holdings of 30-50 MHz in the 3.6-3.8 GHz band in this award and, if successful, would therefore hold spectrum in two non-contiguous blocks within 3.4-3.8 GHz.
- 5.256 In discussions with Ofcom, MNOs have pointed out that it is currently not possible to aggregate separate spectrum carriers in non-contiguous holdings within the 3.4-3.8 GHz band (e.g. aggregate two non-contiguous carriers of 40 MHz). *Non-contiguous intra-band carrier aggregation*, as this type of aggregation is known, is currently available for 4G technology but we think it is unlikely to be supported in early 5G NR devices.
- 5.257 Without non-contiguous intra-band aggregation, it is still possible to deploy 5G NR on separate, non-contiguous carriers within the 3.4-3.8 GHz band to increase the overall capacity of a cellular site.
- 5.258 We recognise that, with or without carrier aggregation, there will be some small to moderate capacity inefficiencies associated with using 5G NR in two non-contiguous spectrum blocks, when compared with a single spectrum block of the same total bandwidth. From our discussions with mobile operators we understand that the capacity penalty might be in the range of 2 to 15%, including losses to additional guard bands and additional signalling overheads.¹⁴⁶
- 5.259 The proximity (i.e. closeness in frequency) of separate, non-contiguous carriers within the 3.4-3.8 GHz band may also be relevant, as it is not possible to deploy a single active antenna system for separate carriers if the radio equipment at the base station does not cover the necessary frequency range.¹⁴⁷ Active antenna systems are relatively large and heavy (compared to passive antennas). It may therefore be costlier or not possible for MNOs to deploy separate antenna systems on each mast for multiple spectrum holdings in the 3.4-3.8 GHz band due to issues related to space, weight, wind-load and power. This problem may potentially be exacerbated by the presence of network sharing agreements

¹⁴⁶ The 2 to 15% penalty range considers several scenarios when operating two discontinuous carriers instead of a single 100 MHz carrier. The lower end of this range considers the loss associated with more guard bands only. The middle of this range also accounts for the typical losses associated with using non-contiguous intra-band carrier aggregation or load balancing in a heavily loaded network. The higher end of this range is based on the maximum losses associated with discontinuity as reported to us in further discussions with certain MNOs, [REDACTED].

¹⁴⁷ We discuss responses from industry on the bandwidth supported by active antenna systems in more detail in 'Early deployment of 5G' in annex 7.

such as MBNL and Beacon/CTIL where the operators are already sharing base station masts.¹⁴⁸

- 5.260 Having considered these issues, however, we would expect the limitations set out above, and inherent to the early stage of the new technology, will reduce in the future as the technology develops and matures. For instance, it is possible that intra-band carrier aggregation could be made available in mobile handsets in the future or that MNOs overcome some of the technical and commercial challenges to deploy active antenna systems jointly, as part of their network sharing agreements.
- 5.261 In the longer term, we expect technology to develop and provide MNOs with further solutions to offer competitive services. For example, MNOs deploying active antennas for a smaller carrier of 40 or 50 MHz may be able to offer additional capacity in targeted areas through small cell deployments in other bands. In addition, MNOs with holdings spanning a wide range can still deploy active antenna systems for a selected carrier (e.g. 40 MHz only in the 3.4 GHz band).
- 5.262 Were these equipment limitations to persist after the auction, and some MNOs to only have fragmented holdings in the 3.4-3.8 GHz band, we nonetheless consider that they would be unlikely to significantly affect the MNOs' ability to compete, especially in the longer term. While recognising there might be cost inefficiencies in the early stages of 5G deployments, we do not expect these disadvantages to endure or significantly distort competition in the longer term.
- 5.263 In addition, we consider that the issue of fragmentation in the band may be solved in other ways. As a result of the auction, some MNOs may obtain spectrum that is close enough to their 3.4 GHz holdings to fall within the range of a single active antenna unit – or they could consider trading their holdings in order to get contiguous or proximate blocks. In section 6 we discuss options to defragment the 3.4-3.8 GHz band.

Steps 2 and 3 – Severity of the effect on competition and likelihood of the outcomes occurring

- 5.264 If one or more of the MNOs ceased to be credible because they did not have a long-term route to 5G services that matter to consumers, it would have a significant negative effect in the market as it would materially decrease the level of competition.
- 5.265 However, as we have outlined above, we do not think this is a likely outcome.
- 5.266 Furthermore, we have also found that there are no concerns related to asymmetry in 5G spectrum in general and 3.4-3.8 GHz in particular.

¹⁴⁸ There are currently two network sharing arrangements in operation in the UK market – the MBNL agreement between H3G and EE, and the CTIL or Beacon agreement between O2 and Vodafone. These agreements allow operators to share passive network elements (such as masts, cabinets and mobile backhaul connections) and/or active elements such as radio equipment.

Steps 4 and 5 – Relevant competition concerns and competition measures

- 5.267 As outlined above, we would be concerned if an MNO did not have a long-term route to be able to offer 5G services that consumers will value in the future. However, we have concluded that this is unlikely to happen. Therefore, we do not think there are any relevant competition concerns.
- 5.268 As there are no relevant competition concerns, we do not propose any competition measures relating to 5G spectrum.

Competition concern 2d: The risk that very asymmetric shares in low frequency spectrum would weaken competition

Summary

- 5.269 In this sub-section, we assess whether competition could be weakened by asymmetry in low frequency spectrum holdings following the auction.
- 5.270 The MNOs' existing holdings of low frequency spectrum are fairly asymmetric, and we do not currently have any firm plans to auction further low frequency spectrum. However, we consider there is no material risk to competition from potential asymmetries in low frequency spectrum. We have not therefore proposed any competition measures for low frequency spectrum.
- 5.271 In the 4G auction in 2013, we imposed a cap on low frequency spectrum to address potential competition concerns relating to the ability of MNOs with no low frequency spectrum to provide coverage for basic (i.e. less data-intensive) services. In contrast to that auction, all MNOs now hold some low frequency spectrum which will allow them to provide good quality coverage in most contexts.
- 5.272 All MNOs provide coverage of voice and data services of at least 200kbps via either 3G or 4G basic data coverage to 99% of outdoor premises, and good quality 4G coverage (of at least 2Mbps) to well over 98% of outdoors premises. As such, there is little room for improvement on these specific metrics. Despite its lower holdings of low frequency spectrum, BT/EE performs better than O2 and Vodafone in terms of current 4G landmass and outdoor premises coverage, though less well on indoor 4G coverage. On the basis of information provided by BT/EE on its roll-out plans until June 2019, its coverage is likely to increase further before the auction. H3G, which also has little low frequency spectrum, is ahead of O2 – and comparable to Vodafone – on landmass 4G coverage, comparable to the other MNOs on outdoor premises coverage and behind O2 and Vodafone on indoor premises coverage.
- 5.273 While high capacity services are generally more effectively provided over mid frequency spectrum (due to the larger available bandwidth), low frequency spectrum may be the only spectrum able to reach users in harder-to-serve areas deep indoors, absent alternative solutions such as Wi-Fi. Given that BT/EE and H3G have some low frequency spectrum, but

less than O2 and Vodafone, they may be disadvantaged in providing high capacity services in harder-to-serve indoor locations.

- 5.274 High capacity services could include many people requiring mobile services in crowded harder-to-serve locations (e.g. a train station at rush hour) or few users demanding very data-intensive services in harder-to-serve locations. We consider that, in a residential setting, alternative solutions – such as offload onto Wi-Fi – are likely to be largely effective in serving such demand, particularly in the longer term.
- 5.275 Many users will also have access to alternative solutions at work, while travelling, and in other locations, and these solutions may improve further in the future. We note in particular that the large footfall in crowded harder-to-serve locations could make small cells and femtocells (or Wi-Fi based solutions) more viable from a cost perspective, which would diminish the need for low frequency spectrum in such situations.
- 5.276 Overall, we are uncertain how the demand for high capacity services in non-residential harder-to-serve locations will evolve. We do not consider it to be a key component of demand at present, nor do we consider that it is an important driver for consumer choice of mobile provider.
- 5.277 In any event, demand for high capacity services is just one element of the quality of coverage experienced by consumers. The other aspects of coverage, in which operators perform similarly despite differences in low frequency holdings, are likely to remain important. There are also alternative means that operators with small amounts of low frequency holdings could pursue to improve this aspect of coverage if it were to increase in importance in the future.
- 5.278 Finally, we note that coverage – along with capacity, pricing and other services – is only one dimension of competition. We do not consider that all MNOs need to be equally placed in all dimensions of competition to compete effectively. Indeed, consumers may benefit from diversity in product offerings, given their differing preferences and willingness to pay for services. In this respect, we note that BT/EE is a strong competitor overall due to its significant spectrum holdings and H3G's 3.4 GHz and 3.6 GHz holdings put it in a strong position with regard to 5G. We do not consider the ability of these operators to compete for customers is likely to be materially affected by a relative disadvantage in this one aspect of coverage (i.e. data-intensive services in harder-to-reach areas).

Step 1 - Which auction outcomes might give rise to competition concerns?

Our concern is about asymmetry of low frequency spectrum shares and not credibility

- 5.279 As we set out below (from paragraph 5.343), we consider that a minimum level of coverage is necessary for an MNO to remain credible. We consider that all MNOs will be able to maintain sufficient coverage levels to remain credible even if they do not win any spectrum in the auction.
- 5.280 Our potential competition concern is that very asymmetric holdings in low frequency spectrum could weaken competition, either by:

- a) **Weakening existing MNOs:** By harming the ability one or more MNOs (those with significantly less low frequency spectrum than other operators) to provide good quality coverage, particularly in harder-to-serve areas (such as in deep indoor locations), damaging their ability to win or retain customers, and so weakening the constraint on rivals; or
- b) **Creating an unmatched competitive advantage:** By enabling an MNO (because of a large share of low frequency spectrum) to offer significantly better quality coverage than rivals, which cannot be economically matched through other means (such as alternative solutions or building more sites), meaning that those rivals would place less constraint on that MNO.

5.281 Such asymmetric holdings could arise if BT/EE and/or H3G won little or none of the available 700 MHz spectrum, or if O2 and/or Vodafone won much or all the available 700 MHz.¹⁴⁹ We now set out why such outcomes might be a cause for concern. We subsequently consider how serious any concern that arose might be.

What is good quality coverage from a competitive perspective?

- 5.282 To provide good quality coverage in a competitive market, MNOs need to provide a consistent and reliable customer experience across a range of services and locations:
- a) The signal strengths, data speeds, and consistency of service needed for good quality coverage (including network reliability) depend on the type of service and the location being served. The distinction between less data-intensive mobile services (such as voice, SMS, email and web browsing) and more data-intensive services (such as video streaming) is relevant for the competition concern we are considering.
 - b) Customers use mobile services at home, at work, while travelling and in other settings such as public buildings, and these can be in urban or rural areas, outdoor or indoors, and can include harder-to-serve locations. Harder-to-serve locations are more challenging to reach with a macro cell network and include locations at cell edges (where the mobile signal is weak) and deeper within buildings which experience high building penetration losses ('deep indoor' areas). A significant share of deep indoor locations will be in urban and suburban areas.¹⁵⁰
- 5.283 The relative importance of different usage scenarios for the overall customer experience, and thus competition, will depend on how often customers are in these scenarios and whether there are other means to get the same service (e.g. Wi-Fi or repeaters). MNOs' different network configurations and spectrum portfolios mean their relative performance can vary across these different usage scenarios.
- 5.284 We would expect MNOs' commercial decisions on coverage to be driven by a trade-off between (i) the importance of coverage to competition and consumers and (ii) the cost of

¹⁴⁹ We recognise both could occur simultaneously, and indeed the occurrence of one makes the other more likely.

¹⁵⁰ "Shallow indoor" areas are those areas closer to windows and exterior walls which experience smaller building penetration losses.

providing that coverage.¹⁵¹ MNOs may not therefore find it commercially attractive to deliver a sufficiently high standard of coverage in all areas where it is socially valuable. Coverage obligations can be used to guarantee coverage in such areas, and these obligations will thus also influence coverage levels.

- 5.285 In chapter 4, we discuss that our proposed coverage obligations must be met at levels of quality that provide consumers with the kind of experience they expect today, with reliable voice calls and a high probability of access to speed of at least 2 Mbps. These standards were set in line with the coverage metrics reported in the Connected Nations 2017 report, which are chosen to capture a broad range of uses.¹⁵²
- 5.286 Our assessment of MNO's competitive performance in terms of coverage uses the same Connected Nations thresholds. However, we also recognise that:
- a) These metrics do not capture all aspects of coverage which may matter for competition (e.g. coverage in harder-to-serve areas).
 - b) Over time, consumer expectations for coverage will be influenced by, and possibly change, due to technological developments and changes in the quality of coverage delivered by MNOs.

The key advantage of low frequency spectrum is its contribution to good quality coverage

- 5.287 We consider that the ability to provide good quality coverage is the most likely means through which differences in low frequency spectrum holdings could adversely affect competition after the auction.
- 5.288 Outside of its coverage benefits, low frequency spectrum does not offer a distinct competitive advantage in other respects such as capacity (see paragraph 5.143 onward), 5G services (see paragraph 5.203 onward) or other services and uses such as fixed wireless services (apart from coverage). We therefore focus our low frequency assessment on coverage.
- 5.289 In line with our position at the time of the 2013 4G auction, we consider there are harder-to-serve areas in which low frequency spectrum will have an advantage in providing coverage. As set out in annex 8, the propagation characteristics of lower frequency spectrum mean that, compared to higher frequency bands, it is particularly suited to allowing MNOs to reach customers in harder-to-serve locations and providing wider coverage in a cost-effective manner. That is, there will be some locations which can only be reached by low frequency spectrum because they are either inherently harder-to-serve or

¹⁵¹ This explains, for example, why MNOs tend to target areas with higher concentrations of customers.

¹⁵² In the Connected Nations report (<https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research>) we say that a good consumer experience requires that for voice calls “nearly all 90-second telephone calls should be completed without interruption” and for data services “nearly all connections should deliver a speed of at least 2Mbit/s. This is fast enough to allow users to browse the internet and watch glitch-free mobile video”. Based on these definitions and data from consumer handsets, we computed the signal thresholds needed to meet these targets 95% of the time for both indoor premises and outdoor areas. This implies that a mobile operator is required to deliver a 4G signal strength of –105 dBm to achieve outdoor geographic coverage, and a 10 dB higher signal strength to provide a similar good experience indoors.

not close enough to existing network sites where higher frequency spectrum is deployed. As noted above, these locations include deep indoors and remote areas.

- 5.290 We have conducted modelling¹⁵³, set out in annex 10, to compare the coverage that different networks may be able to achieve when using different spectrum bands and carrier bandwidths. This analysis compares the coverage performance of networks built around 1800 MHz and sub-1GHz (700 MHz) spectrum.
- 5.291 We have used downlink Single User Throughput (SUT) as a proxy for the quality of coverage that a user might experience, as it is a measure of the data rate that could theoretically be delivered to a single user if the entire resources of the cell site were available to that user at any instant in time. We compare the results in relation to two SUT values: 2 Mbps (which, for the purposes of this analysis, we consider to be representative of basic connectivity) and 10 Mbps (which, for the purposes of this analysis, we consider representative of a data-intensive service).
- 5.292 In order to compare sub-1 GHz with 1800 MHz, and different quantities of sub-1 GHz spectrum, we have modelled the following three different network configurations:
- i) 2 x 20 MHz of 1800 MHz and 18,000 sites nationally;
 - ii) 2 x 10 MHz of 700 MHz and 16,000 sites nationally; and
 - iii) 2 x 5 MHz of 700 MHz and 16,000 sites nationally.
- 5.293 The modelling shows that, due to its more favourable propagation characteristics, low frequency spectrum (700 MHz in the model), when compared to spectrum at higher frequencies (1800 MHz), has an advantage in providing service to harder to reach locations such as indoors (shallow and deep). This advantage can be offset to a certain extent by deploying a denser network (more sites) and wider carriers. For instance, our analysis shows that a network with 2 x 20 MHz of 1800 MHz and with approximately 10% more sites can provide service to more indoor locations than a network with 2 x 5 MHz of 700 MHz. However, the same 1800 MHz network is not quite able to match the performance of a 700 MHz network with a 10 MHz carrier (despite having a denser site grid and twice the carrier bandwidth). More specifically, the model shows:
- lower frequency spectrum (2 x 10 MHz of 700 MHz) allows operators to provide a given level of customer experience (proxied by single user throughput (SUT)) to a larger share of indoor locations (both shallow and deep indoors) than a network based on 1800 MHz (2 x 20 MHz of 1800 MHz), particularly in deep indoors locations;
 - when comparing a network based on 2 x 5 MHz of 700 MHz with a network based on 2 x 20 MHz of 1800 MHz the advantage of low frequency spectrum is less evident for

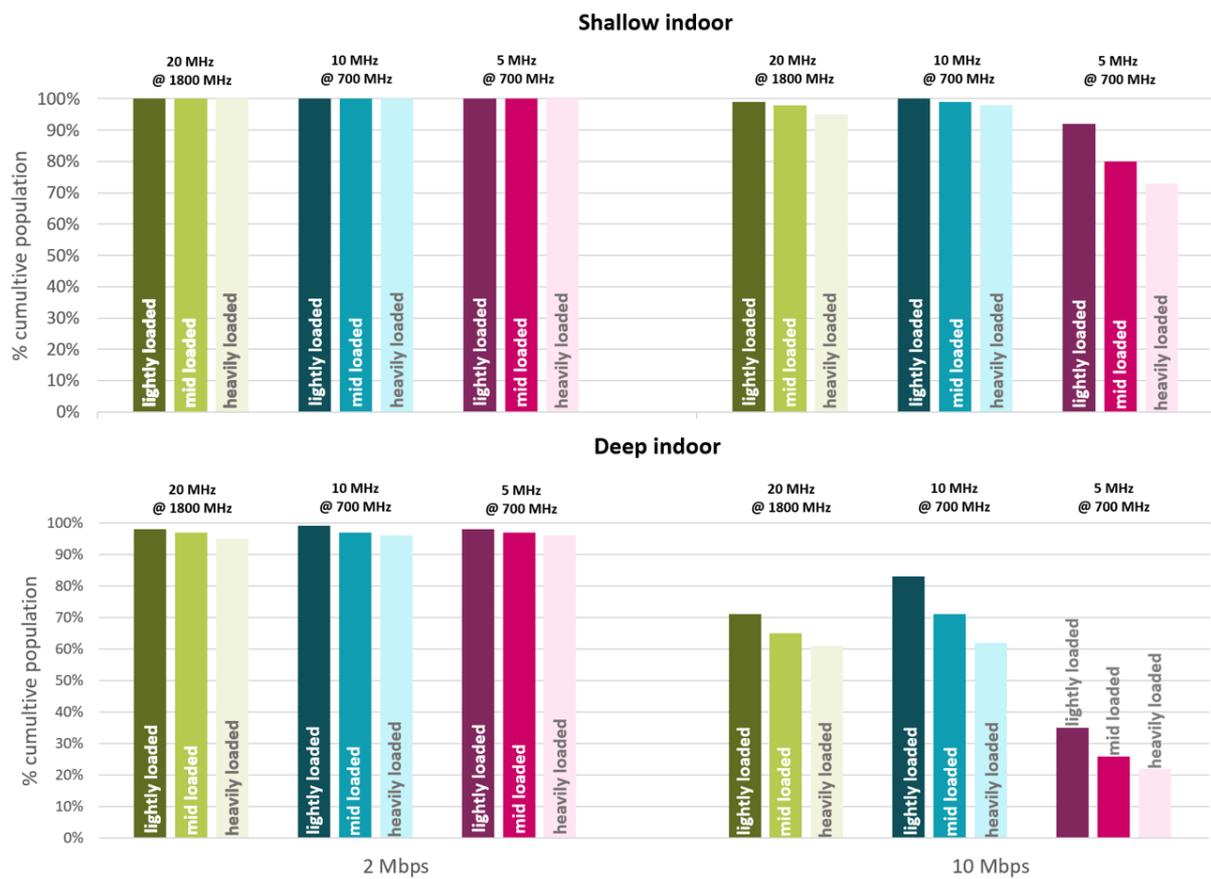
¹⁵³ We believe that the model is useful in comparing the relative variation in performance between macro-cell networks operating at different frequencies and bandwidths. It is less useful in providing information on absolute performance. The results of our model should not be taken as a definitive prediction of macro-cell network performance.

shallow indoor locations (especially for basic connectivity characterized by SUT \geq 2 Mbps¹⁵⁴);

- in the case of deep indoor locations, a network based on 2 x 10 MHz of 700 MHz can outperform a network with 2 x 20 of 1800 MHz (i.e. with twice the bandwidth), though a network based on only 2 x 5 MHz of 700 MHz may not have sufficient bandwidth for more data-intensive services characterized by a SUT \geq 10 Mbps.¹⁵⁵

5.294 Figure 5.8 and Figure 5.9 below show the percentage of cumulative population that achieve a minimum SUT \geq 2 Mbps and \geq 10 Mbps respectively under different network loadings and indoor environments¹⁵⁶, when the three networks are modelled under the same conditions.

Figure 5.8: Indoor coverage for the 0-50% most densely populated areas of the country



¹⁵⁴ We are using a SUT \geq 2 Mbps to represent basic connectivity.

¹⁵⁵ We are using a SUT \geq 10 Mbps to represent more data intensive services.

¹⁵⁶ As explained in annex 10, by network loading we mean the likelihood of having a worse service from a base station impacted by interference from other cells. The results are split into the three areas we have defined in terms of density of population. We extract the relative performance, measured in SUT, of different networks tested under the same propagation and interference conditions.

Figure 5.9: Indoor coverage for the 50%-80% next densely populated areas of the country



5.295 However, we also recognise that:

- a) There are means other than by deploying more low frequency spectrum by which MNOs can, in principle, improve their quality of coverage. These include building more sites and upgrading existing sites, using Wi-Fi offload and voice-over-Wi-Fi, or using sites with different characteristics such as small outdoor and indoor cells. We discuss these further in annex 8.
- b) Despite these advantages, there are nonetheless limitations to the in-building coverage low frequency spectrum can provide. In general, it is becoming more difficult to provide good coverage indoors, no matter what spectrum is used. This is, at least in part, because of the changing characteristics of the building stock – modern building tends to use more thermally efficient materials, which have higher building entry losses. Also, our knowledge of building entry loss has advanced since 2012. More recent evidence suggests that for the bands we are considering in this assessment the relative advantage of low frequency spectrum over mid frequency spectrum, when it

comes to building entry loss, is smaller than the advantage we assumed in 2012, particularly for deep indoor locations.¹⁵⁷

Which bands constitute low frequency spectrum?

- 5.296 In this award, we are awarding 700 MHz spectrum, which is better at covering large areas and penetrating into buildings than spectrum at higher frequencies. In addition to 700 MHz spectrum, we also consider 1400 MHz downlink-only spectrum along with sub-1 GHz spectrum in the pool of low frequency spectrum.
- 5.297 However, we recognise and take account of possible practical limitations in using the 700 MHz downlink-only and 1400 MHz downlink-only spectrum, in the short-term at least. This is discussed further in annex 8. We consider that our overall view on competition concerns relating to low frequency spectrum is not sensitive to whether or not the 700 MHz and 1400 MHz downlink-only spectrum is included in the pool of low frequency spectrum.
- 5.298 While the 1800 MHz and 2100 MHz bands (which we consider to be mid frequency) are used to provide coverage by some MNOs, we consider it appropriate to assess competition issues only in relation to the bands that we have defined as low frequency spectrum (i.e. up to and including 1400 MHz). This is because, as set out above, our analysis suggests that low frequency spectrum has some advantages, relative to mid frequency spectrum, for providing coverage to harder-to-serve areas (e.g. deep indoor locations).

The auction could have a significant long-term influence on shares of low frequency spectrum

- 5.299 As set out in Figure 5.2, low frequency spectrum shares are already quite asymmetric, with BT/EE and H3G holding substantially less low frequency spectrum than either O2 or Vodafone. The 700 MHz spectrum available in the auction offers an opportunity for MNOs to significantly increase their holdings of low frequency spectrum. There are no firm plans for further low frequency spectrum to be released for at least the medium term,¹⁵⁸ so the MNOs' holdings of low frequency spectrum may persist for some time after the auction.

All MNOs hold some low frequency spectrum, unlike in 2013

- 5.300 In our competition assessment for the 2013 4G auction, we noted that EE and H3G held no low frequency spectrum.¹⁵⁹ We considered that MNOs with sub-1GHz spectrum were likely to have some advantage relative to those without it, though we concluded that it was not necessary for credibility.¹⁶⁰

¹⁵⁷ See Recommendation ITU-R P.2109. These ITU-R P.2109 shows that the difference in building penetration losses between sub-1 GHz bands and higher frequency bands around 2GHz is smaller than the difference we assumed in 2012, meaning low frequency spectrum has relatively less advantage in penetrating into buildings. See annex 10 for further details.

¹⁵⁸ We discuss on the 1492-1517 MHz band in annex 8.

¹⁵⁹ EE's 2G and 3G networks were (and still are) based on its 1800 and 2100 MHz spectrum. H3G's 3G network used 2100 MHz spectrum

¹⁶⁰ 2012 Statement, paragraph 4.77.

- 5.301 We were concerned that MNOs without sub-1 GHz spectrum would be disadvantaged in providing coverage to harder-to-serve areas (e.g. deep indoor locations). We found these disadvantages were more pronounced for less data-intensive services (i.e. what we referred to as basic connectivity), that is voice and low-rate data services such as email and web browsing.¹⁶¹
- 5.302 In light of these concerns, we imposed a safeguard cap of 2 x 27.5MHz of sub-1 GHz spectrum (42.4%) for the 2013 4G auction. This measure, along with the spectrum reservation,¹⁶² addressed our concerns by reducing the risk that one or more operators would not hold sub-1GHz spectrum after the auction.¹⁶³
- 5.303 All operators now hold low frequency spectrum,¹⁶⁴ and hence there is a narrower scope for concern compared to the 4G auction. Our concerns in the statement issued in 2012, ahead of the 4G auction, also related to less data-intensive services. As demonstrated in the coverage statistics summarised in Figure 5.10, Figure 5.11 and Figure 5.12, BT/EE and H3G's existing low frequency holdings are now likely to be sufficient for providing less data-intensive services to a significant number of customers in most scenarios.¹⁶⁵ Unlike the 4G auction, the potential risk to competition is the potential inability to provide coverage with sufficient capacity to cater for demand in harder-to-serve areas.

The key potential competitive impact of asymmetric low frequency holdings is in providing coverage for high capacity services in harder-to-serve areas

- 5.304 Any potential concern then stems from the asymmetry in low frequency spectrum holdings rather than from any MNOs having no low frequency spectrum. We consider that there could be advantages to holding more low frequency spectrum, even in a context where all operators hold at least some low frequency spectrum. Extra bandwidth could give an advantage in providing additional capacity in harder-to-serve-areas by:
- a) providing higher data throughput to individual users of data-intensive services (such as higher definition video streaming, video calls, etc.); and
 - b) allowing the operator to serve simultaneously a higher number of users, in those harder-to-serve locations where higher frequencies are generally not able to reach.
- 5.305 As set out above, we have modelled the impact of additional low frequency spectrum on downlink data throughput (see annex 10). This modelling shows that additional low frequency spectrum would provide greater throughput and allow an MNO to provide a given level of throughput to a materially higher number of consumers in both shallow and

¹⁶¹ We said for a single user this might require speeds typically in the range 100 to 500kbits/s (2012 Statement, paragraph 4.79). We also noted that it was not necessarily the case that lower frequencies gave better coverage for higher rate data services, if the higher frequencies were available in greater bandwidths.

¹⁶² The 4G auction had a flexible reservation of portfolios of spectrum for either a new entrant or the smallest incumbent national mobile competitor (H3G). Three of the four portfolios included 800MHz spectrum (see Table 1.1 of the 2012 4G Auction Statement).

¹⁶³ 2012 Statement, paragraphs 1.12 and 4.313.

¹⁶⁴ EE and H3G both won 2x5MHz of 800MHz spectrum in the 2012 4G auction. H3G also acquired 20MHz of 1400MHz downlink-only spectrum from Qualcomm (as did Vodafone) since the 4G auction.

¹⁶⁵ This may not be the case in areas with a large number of users, where a small holding of low frequency spectrum may not be able to serve all users in hard-to-serve areas.

deep indoor environments. This suggests that due to their lower low frequency holdings H3G and BT/EE may have issues in providing:

- a) Good quality of service for data-intensive services in harder-to-serve areas. This may occur when users enter indoor locations and are unable to use applications that require high speeds. The impact on competition would be greatest for those customers who most value these services.
- b) Connectivity to a large number of users in crowded harder-to-serve locations, such as railway stations and shopping centres, where low frequency spectrum better penetrates walls and other obstacles. Having smaller holdings in such cases may not allow the operator to offer the necessary quality of service to the large number of customers using mobile services in these locations.

Outcomes which could raise competition concerns

- 5.306 After the auction, the most likely source of a competition concern due to low frequency spectrum would be differences in MNOs' abilities to provide capacity in harder-to-serve areas. The auction outcomes which could raise these concerns are if:
- a) BT/EE and/or H3G won little or none of the available 700 MHz spectrum; or
 - b) O2 and/or Vodafone, either individually or collectively, won much of the available 700 MHz spectrum.
- 5.307 In principle, these outcomes could either weaken the MNOs with less low frequency spectrum or allow MNOs with more low frequency spectrum to have an unmatched advantage. In the following section, we assess the likely effect of these outcomes on competition.

Step 2 – Severity of the effect on competition

MNOs perform similarly on available coverage and consumer satisfaction metrics, despite asymmetries in low frequency holdings

- 5.308 The scope for further asymmetry to harm competition depends on how MNOs currently compare in terms of coverage given the existing asymmetry.
- 5.309 Unlike in 2012, we now have access to data on MNOs' network coverage which we publish as part of our annual Connected Nations report.¹⁶⁶ In annex 9, we use a number of metrics from this dataset to compare MNOs' coverage at September 2018. These metrics are reproduced below.¹⁶⁷

¹⁶⁶ <https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research>

¹⁶⁷ For 4G coverage we use a 2Mbps quality of service threshold. For 3G or 4G basic data coverage, we use a lower threshold of 200Kbps which can be met by either 3G or 4G (note, such speeds however are unlikely to be sufficient for certain services, especially in the future). Geographic landmass coverage represents the percentage of landmass where good coverage is likely to be available. Outdoor premises coverage represents the percentage of premises where a good mobile signal is likely to be available outdoors. Generic indoor coverage measures the

Figure 5.10: Voice coverage

	Geographic Landmass	Outdoor premises	Generic Indoor
BT/EE	85.0%	99.4%	95.8%
O2	90.4%	99.8%	99.1%
H3G	84.8%	99.5%	95.9%
Vodafone	90.4%	99.8%	98.6%

Source: Ofcom analysis of MNO data, September 2018

Figure 5.11: Basic data coverage offered using 3G and 4G technology (with download speed of at least 200 Kbit/s)

	Geographic Landmass	Outdoor premises	Generic Indoor
BT/EE	91.8%	99.9%	99.2%
O2	88.5%	99.8%	99.2%
H3G	89.7%	99.9%	99.2%
Vodafone	89.2%	99.8%	99.0%

Source: Ofcom analysis of MNO data, September 2018

coverage that a consumer will experience when using their phone at home, at work or in a shop. It allows a 10dBm penetration loss compared to the threshold for outdoor premises coverage, corresponding to the loss usually incurred if a mobile phone is located within a building but only a few metres away from a typical window. It is not directly comparable to either shallow indoor coverage or deep indoor coverage, however we can note that the penetration losses assumed for deep indoor coverage are usually far larger (see annex 8). It can be observed that some voice coverage percentages are slightly lower than their equivalent 3G or 4G basic data coverage percentages. This can be attributed to the different threshold applied for 3G or 4G basic data coverage and voice coverage by 4G, which has a significant contribution to the overall generic data or voice coverage by 2G, 3G, and 4G technologies combined. See annex 9 for further discussion.

Figure 5.12: Good quality 4G coverage (with download speed of at least 2Mbit/s)

	Geographic Landmass	Outdoor premises	Generic Indoor
BT/EE	84.4%	99.1%	88.4%
O2	74.4%	98.9%	94.8%
H3G	78.4%	98.6%	89.4%
Vodafone	78.6%	99.0%	93.7%

Source: Ofcom analysis of MNO data, September 2018

5.310 In summary:

a) In respect of **data** coverage:

- On a landmass basis, BT/EE's coverage is a few percentage points ahead of H3G, Vodafone and O2 in terms of both 3G or 4G basic data coverage (200Kbps) and 4G coverage (2Mbps), with O2 lagging further behind in terms of 4G coverage.
- For outdoor premises coverage, there is limited difference between MNOs, and indeed limited room for improvement, as all four MNOs are above 99% coverage in terms of the 3G or 4G basic data coverage and close to 99% in terms of 4G coverage.
- In terms of generic indoor coverage, all MNOs exceed 99% for 3G or 4G basic data coverage, but BT/EE and H3G lag Vodafone and O2 in terms of 4G indoor coverage by 4-6 percentage points.

b) In respect of **voice** coverage, BT/EE and H3G lag O2 and Vodafone by about 5 percentage points on a landmass basis, and by about 3 percentage points in terms of generic indoor coverage, reflecting the advantages of low frequency spectrum deployment. All MNOs are above 99% in terms of outdoor premises coverage.

5.311 As shown in annex 9, 4G roll-out is still not complete and MNOs show significant improvements in coverage over time. We also have MNO's coverage predictions for June 2019 which show [REDACTED]. Given this, we might expect MNOs' absolute levels of coverage to improve further ahead of the auction.

5.312 Evidence relating to customer satisfaction and network reliability suggests current asymmetries in holdings are not affecting perceived consumer experiences:

a) As set out in annex 9, Rootmetrics network performance research shows that BT/EE and H3G, despite their smaller low frequency spectrum holdings, outperform O2 and Vodafone in terms of network reliability, which is an aspect of quality of coverage.

- b) Evidence in annex 6 on consumer satisfaction with reception, signal strength and indoor coverage specifically does not show material differences across the MNOs.
- c) Tests on consumer devices reported in Ofcom's May 2018 Consumer Mobile Experience showed no significant differences in the failure rates of 3G or 4G connections across MNOs,¹⁶⁸ or in regard to dropped call rates due to lack of service.

5.313 Overall, this evidence does not show that BT/EE and H3G are lagging their competitors to any significant extent in terms of measured coverage and customer satisfaction with coverage/reliability, and indeed, they are outperforming O2 and Vodafone in some respects.

BT/EE and H3G could nonetheless struggle to provide high capacity services in harder-to-serve areas without more low frequency spectrum

5.314 We do not have metrics for coverage in harder-to-serve areas (e.g. deep indoors). As set out above and in annex 10, our modelling suggests that BT/EE and H3G may be at a disadvantage in these areas.¹⁶⁹

5.315 We also note that, in principle, EE and H3G's lack of low frequency bandwidth could hinder them in the (predominately rural) areas they serve only with 800 MHz spectrum. However, at the same time, an MNO is unlikely to need large bandwidths to provide good quality coverage in more remote areas as users are typically thinly spread. We do not have evidence that BT/EE and H3G are facing any such constraints in practice due to their smaller holdings of low frequency spectrum.

Coverage is important to consumers, but the importance of capacity in harder-to-serve areas is unclear

5.316 If the differences in coverage due to asymmetry in low frequency holdings are to influence competition, then coverage must be an important element of consumer decision making. In annex 6 we have assessed what factors are important for mobile customers when choosing a provider. We find that quality and reliability of network experience, including coverage, are indeed an important driver of consumer choice.

5.317 We have no evidence which shows that additional capacity in harder-to-serve areas is a particularly important aspect of the consumer experience or driver of consumer choice, and therefore no evidence to suggest that existing differences in capabilities are influencing competition at present. In annex 6, we noted that web-browsing and voice calls are classified as important by a higher share of mobile users than the more data-intensive uses such as streaming video content and uploading or downloading large files. Historically, customers may generally have expected to rely on Wi-Fi for data-intensive

¹⁶⁸ <https://www.ofcom.org.uk/research-and-data/telecoms-research/mobile-smartphones/consumer-mobile-experience>

¹⁶⁹ On the other hand, it is worth noting that several operators have highlighted the potential problem of self-interference when using low frequency spectrum in the densest parts of their networks. This is because the otherwise advantageous propagation characteristics of low-frequencies means that self-interference might occur over a larger area than would be the case with higher frequencies thus partially negating some of the advantage of low frequencies.

services in harder-to-serve areas, rather than a direct connection from their devices to a macro cell network.

- 5.318 Additionally, providing coverage for high capacity services in harder-to-serve areas is just one element of a much wider concept of quality of coverage. As set out above, MNOs perform similarly in other aspects of coverage. Therefore, any gap in performance in this respect would need to be very significant to influence MNOs' overall position in terms of quality of coverage.
- 5.319 However, as discussed in annex 6, data volumes have been growing, as has the relative weight customers place on data elements of their service in their choice of operator (e.g. data speeds), and these trends can be expected to continue. It is therefore possible that in the future, as consumer demand and expectations change, it will be more important for MNOs to provide capacity in harder-to-serve areas.
- 5.320 As a result, we have considered in more detail what operators could do to improve coverage of these services with existing spectrum holdings.

Additional low frequency spectrum is not the only way to improve coverage

- 5.321 The importance of asymmetries in low frequency spectrum holdings for competition depends on the extent to which MNOs can use existing spectrum more effectively or rely on other means to deliver good quality coverage, particularly for providing high capacity services in harder-to-serve locations.
- 5.322 Annexes 7 and 8 sets out the alternatives available to MNOs and assesses the extent to which they can reduce any reliance on low frequency spectrum. In summary:
- a) There remains some scope, particularly for BT/EE, to improve performance for customers in harder-to-serve areas by deploying their existing holdings of 800 MHz on more sites. [REDACTED].
 - b) The key alternative technology for providing good quality coverage in buildings is Wi-Fi.¹⁷⁰ There are also other technologies, such as cellular repeaters, small cells and femtocells,¹⁷¹ which can improve coverage in certain circumstances. For example, we note that MNOs with smaller low frequency holdings could potentially struggle to provide services to large numbers of customers in more crowded harder-to-serve locations (e.g. shopping centres or transport hubs). However, the large groups of users might also make it more cost-effective to deploy alternative solutions (e.g. small/femtocells or Wi-Fi) at these same locations. Overall, there have been significant policy developments and technological advances¹⁷² which mean that these

¹⁷⁰ This does require a fixed broadband connection or fixed wireless access service of sufficient quality. Since we are generally considering built up areas rather than remote areas, we expect this to be present.

¹⁷¹ Acknowledging that these technologies will require backhaul too: cellular repeaters require outdoor mobile coverage; small cells require outdoor coverage, a broadband connection or an FWA connection; and femtocells require a broadband connection or an FWA connection.

¹⁷² For example, on the policy side the broadband universal service obligation (<http://researchbriefings.parliament.uk/ResearchBriefing/Summary/CBP-8146>) will facilitate the use of Wi-Fi and

technologies are easier to deploy and more effective than they were at the time of the 4G auction statement in 2012.

- c) Wi-Fi technology is particularly effective in residential buildings where customers have a fixed broadband connection, and other locations where customers can connect seamlessly to Wi-Fi.¹⁷³ Research shows that for 75% of time spent on smartphones, customers connect using Wi-Fi rather than mobile networks (see annex 7). Voice over Wi-Fi is increasingly being offered by mobile networks and is particularly useful in providing services in areas with poor coverage. In the longer term we expect the use of licence-exempt spectrum, including Wi-Fi, is likely to be far more integrated into 4G and 5G mobile networks.¹⁷⁴ Additionally, the merger of BT and EE leaves it particularly well placed to deploy these alternative technologies. Wi-Fi, along with other solutions, can also assist in providing coverage in the harder-to-serve areas inside public buildings and business premises, although these may be subject to greater restrictions and more limited use.¹⁷⁵
- d) We also consider that network management technologies have improved since 2012 and are able to support more effective load balancing mechanisms, whereby priority on the use of low frequency spectrum is given to users in harder-to-serve areas.

5.323 Our view is that alternative technologies have improved and are a more viable means of filling gaps in the macro cell networks than in the past, particularly as all MNOs now hold some low frequency spectrum which reduces the scope for coverage gaps. There is also scope for BT/EE and H3G to deploy their existing low frequency more widely, and potentially to use it more efficiently. These factors can make a significant contribution to quality of coverage, including for data-intensive services in harder-to-serve areas, and so would reduce any risk to competition from asymmetries in low frequency spectrum holdings.

femtocells and recent regulations now permit greater use of repeaters (<https://www.ofcom.org.uk/consultations-and-statements/category-3/regulations-short-range-devices-mobile-repeaters>). On the technology side, Wi-Fi is widely used to off-load traffic in residential settings (including for more data intensive services).

¹⁷³ Residential Broadband penetration is at 86% among UK adults, and internet usage is higher among mobile users (Broadband penetration figures from Interactive Communications Market Report, Slide 17, Ofcom, <https://www.ofcom.org.uk/research-and-data/multi-sector-research/cmr/cmr-2018/interactive;>); Internet and mobile usage figures from Ofcom Media Literacy Tracker, https://www.ofcom.org.uk/data/assets/pdf_file/0015/113226/Adults-media-use-and-attitudes-report-2018-face-to-face-survey-data-tables.pdf). The Broadband Universal Obligation will further increase the share of homes with access to a good quality broadband connection, particularly in rural locations.

¹⁷⁴ For example, 3GPP Release 16 will allow 5G NR will be able to use licence exempt spectrum without a licenced spectrum 'anchor' as is currently required.

¹⁷⁵ We note that whilst Wi-Fi is an effective supplement to coverage in many hard-to-serve locations, such as deep inside larger buildings, it is not a substitute for a good level of mobile coverage across a whole community (including the reasonable expectation of some in-building coverage). In rural communities, for example, not everyone has broadband, or a Wi-Fi calling enabled handset, while those visiting local shops or attractions, or coming into the area for work, may not be automatically connected to a local network and so could remain uncontactable.

The evidence does not suggest a material risk to coverage and competition from any of the possible auction outcomes for low frequency spectrum

- 5.324 We described above the possible auction outcomes which could lead to very asymmetric holdings (including if BT/EE and/or H3G won none of the available 700 MHz spectrum). In principle, these outcomes could weaken existing MNOs and/or create an unmatched competitive advantage.
- 5.325 MNOs perform similarly on the available coverage and consumer satisfaction metrics, despite asymmetries in holdings. However, these metrics do not include a coverage metric relating to their ability to cater for demand in harder-to-serve areas, which is the most likely competition concern to arise from asymmetry in low frequency spectrum holdings. Modelling suggests that MNOs with smaller low frequency holdings may be disadvantaged in catering for demand in harder-to-serve areas. We have no evidence indicating the importance of this element of quality of coverage at present, but we cannot rule out that it might become more important in the future.
- 5.326 However, this is a relatively narrow aspect of coverage, and indeed different to our concerns in 2012, which related to less data-intensive services in the context of some MNOs having no low frequency spectrum. We also consider that MNOs have other viable means to provide such services in harder-to-serve areas, including continued deployment of existing spectrum and use of alternative solutions.
- 5.327 Additionally, we note that coverage is just one aspect of the overall competitive position of MNOs. BT/EE is a strong competitor overall due to its significant overall spectrum holdings and H3G's 3.4 GHz and 3.6 GHz holdings put it in a strong position with regard to 5G. We do not consider the ability of these operators to compete for customers is likely to be materially affected by a relative disadvantage in one aspect of coverage which is not currently of great importance to consumers.
- 5.328 Overall, we do not think any of the possible auction outcomes for low frequency spectrum (including a situation in which neither BT/EE nor H3G won no 700 MHz spectrum) pose a material risk to competition.

Step 3 - Likelihood of these auction outcomes arising

- 5.329 We have, in any case, used the framework set out from paragraph 5.29 onwards, to consider the likelihood that:
- a) BT/EE and/or H3G win little or none of the available 700 MHz; and/or
 - b) O2 and/or Vodafone, win much or all the available 700 MHz.

Intrinsic value

- 5.330 A number of factors suggest that BT/EE could have a relatively high intrinsic value for low frequency spectrum:

- a) BT/EE has the lowest share of low frequency spectrum. If asymmetry of holdings would put BT/EE at a competitive disadvantage, then it would have a high intrinsic value for acquiring additional low frequency spectrum.
- b) BT/EE has a significantly larger number of subscribers than Vodafone and H3G and a similar number of subscribers to O2. This means that BT/EE has a large base of customers over which to spread the costs and monetise the benefits of any additional spectrum, which will tend to increase its intrinsic value.
- c) BT/EE holds no downlink-only spectrum at present but does have the largest share of overall data traffic (see Figure A6.30 in annex 6), and so may place greater value on the 700 MHz downlink-only spectrum than either Vodafone or H3G, who already hold 20 MHz each in the 1400 MHz band.¹⁷⁶

- 5.331 It could be argued that due to self-interference, site upgrade costs or other issues, MNOs which originally based their network site grid on low frequency spectrum (i.e. O2 and Vodafone) are able to deploy 700 MHz spectrum more cost-effectively, and so have a greater intrinsic value for 700 MHz spectrum than MNOs which based their networks on higher frequency spectrum (i.e. BT/EE and H3G). However, different spectrum portfolios and network configurations will have different advantages and disadvantages. In our view, the overall impact of differences in grid configurations on the MNOs' relative intrinsic values is unlikely to be so large as to significantly influence their likelihood of winning 700 MHz spectrum.
- 5.332 Some factors also suggest H3G could have a relatively high intrinsic value for at least the paired 700 MHz spectrum. Like BT/EE, H3G has a low share of existing low frequency spectrum and, if this were a source of competitive disadvantage, then it would have a high intrinsic value for acquiring additional low frequency spectrum. H3G also has the second largest volume of data traffic, slightly behind BT/EE, and the highest data traffic per subscriber and per MHz of holdings (see Figures A6.31 and A6.32 in annex 6) and so its intrinsic value for any spectrum may be relatively high.
- 5.333 In contrast, if H3G had a low intrinsic value for the 700 MHz band due to a competitive strategy which placed relatively little weight on coverage, then there may not necessarily be a competition concern.
- 5.334 Similarly, if H3G's existing 1400 MHz downlink-only holdings mean they may have a lower value for the 700 MHz downlink-only spectrum than BT/EE and possibly O2 (neither of which hold any 1400 MHz downlink-only spectrum), there may not necessarily be a competition concern in relation to H3G for this spectrum.
- 5.335 O2 and Vodafone already hold a significantly larger share of low frequency spectrum than BT/EE or H3G, and so their intrinsic value for more spectrum may be relatively low (although some or all MNOs could value 700 MHz for providing 5G services).¹⁷⁷ Again, if

¹⁷⁶ Downlink-only spectrum used for SDL provides additional downlink capacity and permits a higher downlink to uplink data ratio. MNOs who already hold this type of spectrum are therefore likely to be less constrained in these respects, and so derive less value from additional downlink-only spectrum, compared to a MNO without downlink-only spectrum.

¹⁷⁷ However, we recognise O2 could value low frequency spectrum from a capacity perspective.

H3G and/or BT/EE were potentially at risk of competitive disadvantage from O2 and/or Vodafone acquiring a large share or all of the available 700 MHz spectrum, then they would have a strong incentive to bid aggressively for it.

Strategic investment

- 5.336 We stated above that there is no material risk to competition even if BT/EE and/or H3G win no 700 MHz spectrum. In line with this, we consider the benefits from strategic investment are likely to be limited and significantly outweighed by the costs. We consider that BT/EE can compete effectively without further low frequency spectrum, and that there would therefore be little to gain from strategic investment in denying BT/EE that spectrum. However, if BT/EE would be materially disadvantaged without additional low frequency spectrum, which we do not believe is the case, BT/EE would be likely to have a high intrinsic value for the 700 MHz spectrum and strategic investment could be costly. A similar argument would apply to H3G's value for 700 MHz spectrum.
- 5.337 In these circumstances, there would be little incentive for strategic investment, and the likelihood of auction outcomes for low frequency spectrum are unlikely to be influenced by the prospect of strategic investment.

Our provisional position on the likelihood of outcomes that could raise competition concerns related to low frequency spectrum

- 5.338 If acquiring 700 MHz spectrum is important for BT/EE's competitive position, it is likely to have a relatively high intrinsic value for the 700 MHz band and would not appear to be at risk of being the target of strategic investment. This suggests that, if it is important for strong competition, there is a low likelihood of BT/EE not winning any 700 MHz spectrum (and an even lower likelihood of a situation where both BT/EE and H3G do not win any 700 MHz spectrum).
- 5.339 If acquiring 700 MHz spectrum is important for H3G's competitive position, it could also have a relatively high intrinsic valuation for the 700 MHz band. We have also noted some possible reasons why a lower value could reflect H3G's competitive strategy rather than an inherently lower ability to win the spectrum it needs for its competitive strength. Also, if H3G has a strong need for 700 MHz, it could trade some of its other spectrum holdings to acquire it.
- 5.340 As explained above, we consider that strategic investment on the part of O2 and Vodafone would be likely to be ineffective as BT/EE and H3G are currently performing well on many measures of coverage, even with their currently low holdings of low frequency spectrum.

Steps 4 and 5 – relevant competition concerns related to low frequency spectrum and need for measures

- 5.341 We identified auction outcomes for low frequency spectrum which, in principle, could create competition concerns. While there may be some likelihood of these outcomes occurring, our view is that, in practice, none of the possible asymmetries in low frequency

spectrum arising from the auction would pose a material risk to competition. Overall, we therefore do not have any material competition concerns related to low frequency spectrum, and so do not propose any competition measures to address potential asymmetries in low frequency spectrum.

Competition concern 1: Risk of there ceasing to be four credible operators

It is important to maintain four credible MNOs

- 5.342 We believe that it is likely that competition between the MNOs would be considerably weaker if there ceased to be four credible competitors. We would be very concerned if we believed that this was a likely outcome of spectrum distributions arising from this auction.
- 5.343 By ‘credible’ we mean that an MNO is able to exert an effective constraint on its rivals – in terms of factors such as the provision of high quality services, competitive prices, innovation and a wide range of services valued by consumers – and so contribute to the overall competitiveness of the market. The loss of a credible competitor would mean that the UK became effectively a three-player market, even if the MNO did not actually cease to operate and exit the market. This would likely be detrimental to consumers, for example through higher prices and/or a deterioration in the quality of services.

Factors which affect credibility

- 5.344 As we note above, an MNO’s competitive position – and therefore, at the limit, its credibility – is not only dependent on its spectrum holdings. In this analysis, however, we consider the role of spectrum in maintaining credibility and focus on capacity, coverage and the ability to deploy 5G.
- 5.345 We consider that an MNO must have a spectrum portfolio to enable it to be sufficiently strong in terms of capacity, quality of coverage and offer a portfolio of services (e.g. 4G and, in the longer term, 5G) to remain credible.
- 5.346 This is consistent with our approach in the competition assessment for the 2.3 and 3.4 GHz auction, and the previous major spectrum auction in 2013.¹⁷⁸ In 2013, we concluded that a minimum level of coverage and capacity were necessary for an MNO to remain credible. We said that providing the highest peak speeds was not necessary for credibility. We considered services with other LTE advantages (e.g. better latency) and concluded that it was unclear whether they were necessary for credibility in the short term, but that they were necessary to remain credible in the long term.
- 5.347 In the July 2017 statement, we again said that a minimum level of capacity and coverage were necessary to remain credible and that in the longer term a route to 5G might be

¹⁷⁸ https://www.ofcom.org.uk/_data/assets/pdf_file/0013/104305/Statement-annexes-Award-of-the-2.3-and-3.4-GHz-spectrum-bands.pdf, paragraph A8.52 onwards.

necessary. Since all MNOs were already providing LTE services, we concluded that this dimension was no longer relevant.

We consider that all four MNOs will remain credible, whatever the result of this auction

- 5.348 In the July 2017 statement we decided that all four MNOs would have spectrum portfolios to remain credible, whatever the outcome of the auction.¹⁷⁹ We had some concerns about [REDACTED], but we did not consider that it would cease to be credible if it did not obtain any more spectrum.
- 5.349 Given that spectrum distribution is less asymmetric than prior to the 2.3 and 3.4 GHz auction, we consider it even less likely that any of the four MNOs would cease to be credible as a result of any outcome in this auction.
- 5.350 The smallest operator, O2, will have 15% of overall spectrum even if it wins none in this auction. This is at the top end of the 10 to 15% range below which we consider there is a material risk of an MNO not having sufficient spectrum to remain credible. We also note that all four MNOs are financially viable, as outlined in paragraphs A6.78 to A6.87 of annex 6.
- 5.351 We, therefore, consider that, even if they win no further spectrum in this auction, it is highly likely that each MNO's spectrum portfolio will enable it to:
- have sufficient **capacity** to remain credible;
 - have a long-term route to a wide range of 5G services; and
 - have good **coverage** for enough of the population (including harder-to-serve areas) to remain credible.

We do not propose any measures to address the potential concern about future credibility

- 5.352 In light of the above, we do not consider that any measures are necessary or proportionate to address the concern that there would cease to be four credible operators.

Consultation questions

Question 2: Do you agree that we have identified the correct competition concerns?

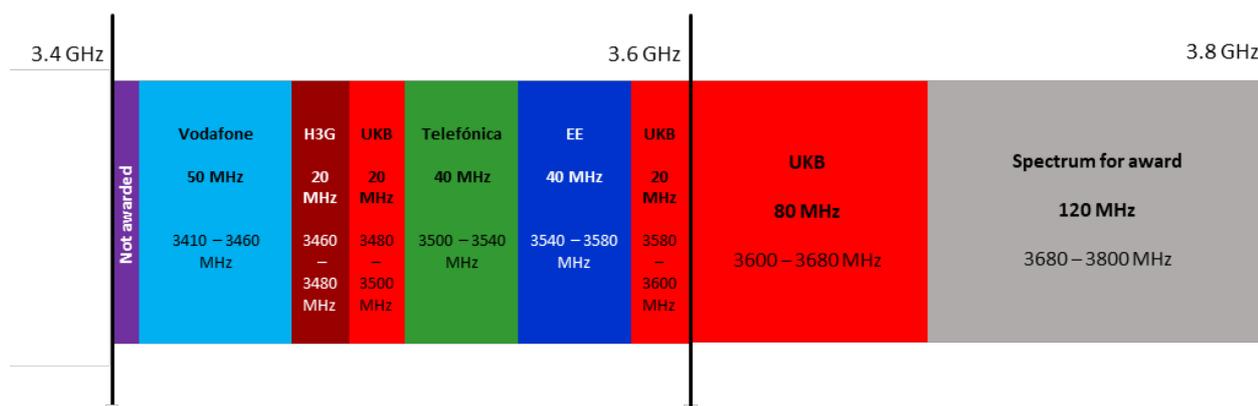
Question 3: Do you agree with our assessment of these competition concerns, and our proposed measure for addressing them? Please give reasons supported by evidence for your views.

¹⁷⁹ https://www.ofcom.org.uk/_data/assets/pdf_file/0022/103819/Statement-Award-of-the-2.3-and-3.4-GHz-spectrum-bands-Competition-issues-and-auction-regulations.pdf, paragraph 6.104 onwards.

6. Defragmentation of the 3.4-3.8 GHz band

- 6.1 We have considered whether it would be desirable to use this auction to seek to defragment spectrum holdings across the entire 3.4-3.8 GHz band.
- 6.2 As we describe in section 2, the 3.4-3.8 GHz band has been harmonised for mobile and identified as part of the primary band for introducing 5G in Europe. There is a general consensus – including among MNOs and European regulatory bodies – that optimal deployment of 5G will be best achieved through large contiguous spectrum blocks.
- 6.3 We note that operators consider a minimum of 80 MHz of contiguous spectrum to be desirable for 5G and we recognise that rearrangement of spectrum holdings could help secure greater contiguity for each licensee, and hence leave less fragmentation of the band. As such, we consider that defragmentation of the wider 3.4-3.8 GHz spectrum may well be desirable, in the interests of citizens and consumers.
- 6.4 The arrangement of spectrum holdings ahead of the auction is illustrated in Figure 6.1 below. H3G, which owns UK Broadband, holds a total of 140 MHz of spectrum in the 3.4-3.8 GHz band, including a contiguous holding of 100 MHz (3580-3680 MHz).¹⁸⁰
- 6.5 H3G/UK Broadband holds 60 MHz of spectrum in the 3.4 GHz band, including 20 MHz at 3460-3480 MHz which H3G acquired in the 2018 auction of the 2.3 and 3.4 GHz bands, and two blocks of 20 MHz, from 3480-3500 MHz and 3580-3600 MHz, which are licensed to UK Broadband.
- 6.6 Of the other three MNOs, Vodafone has the most spectrum in the 3.4-3.8 GHz band (50 MHz), and O2 and BT/EE hold 40 MHz each.

Figure 6.1: Spectrum holdings in the 3.4-3.8 GHz frequency range



¹⁸⁰ On 14 December 2018 Ofcom published a statement varying UK Broadband's 3.6 GHz spectrum access licence. See: <https://www.ofcom.org.uk/consultations-and-statements/category-2/variation-uk-broadbands-spectrum-access-licence-3.6-ghz>. Currently, UK Broadband is also authorised to use an additional block of 4 MHz (3685-3689 MHz) for a transitional period which will come to an end on 14 September 2019.

Benefits of contiguity/proximity

- 6.7 We recognise that defragmentation of the 3.4–3.8 GHz band may well be desirable given the benefits that contiguity of spectrum holdings can bring.
- 6.8 In the absence of contiguous spectrum, an operator may benefit from having its separate blocks of 3.4-3.8 GHz spectrum sufficiently close to each other. This may allow it to avoid higher costs of equipment e.g. it may avoid the requirement to deploy more than one antenna to service frequency bands that are wide apart.
- 6.9 We refer to this issue as the ‘proximity’ of an operator’s spectrum blocks. Although there are advantages in proximity, contiguity is likely to be a better outcome.
- 6.10 We would expect the limitations (set out above and inherent to the early stage of the new technology) will reduce in the future as the technology develops and matures. Our current understanding is that dual connectivity will allow inter-band carrier aggregation (i.e. the aggregation of multiple carriers across different spectrum bands) between 4G and 5G carriers that could allow for higher peak speeds.¹⁸¹
- 6.11 In light of the above, we have considered whether there are steps we could take in this award to facilitate defragmentation of the wider 3.4-3.8 GHz spectrum band. We set out below our views on ideas already put to us by stakeholders, as well as further options that we have considered.

Full 3.4-3.8 GHz band assignment stage in this auction

Stakeholders’ suggestions

- 6.12 We propose that the forthcoming auction of 3.6-3.8 GHz spectrum will involve a principal stage, to determine the amounts of spectrum to be acquired by winning bidders, and an assignment stage, in which bidders make bids to win specific frequencies for those winning blocks.
- 6.13 In response to our June 2018 consultation on the variation of UK Broadband’s spectrum access licence for 3.6-3.8 GHz spectrum, BT/EE, O2 (Telefónica) and Vodafone suggested we should (in the context of the licence variation) have considered the fragmentation of the wider 3.4-3.8 GHz band and identified solutions to defragment it.¹⁸² One solution suggested was to allow or require the existing licensees of spectrum in the 3.4-3.8 GHz band to make their spectrum available in the assignment stage of the forthcoming 3.6-3.8 GHz award. Stakeholders’ suggestions included:

¹⁸¹ As an example, dual connectivity will allow for control information to be sent over a 4G channel and for user data to be sent over up to 3x 4G carriers (e.g. 20 MHz each) aggregated with a single 5G channel (e.g. 80 MHz). This could provide a similar throughput to that available from a single 100 MHz 5G NR channel.

¹⁸² <https://www.ofcom.org.uk/consultations-and-statements/category-2/variation-uk-broadbands-spectrum-access-licence-3.6-ghz>

- a) “*mandatory reassignment*” - requiring all bidders to put their spectrum holdings within the 3.4-3.8 GHz band in the assignment stage of the 3.6-3.8 GHz auction as a condition of participation in the auction; or
- b) “*voluntary reassignment*” - allowing existing licensees, including H3G/UK Broadband, to enter voluntarily their 3.4–3.8 GHz spectrum holdings in the assignment stage of the 3.6–3.8 GHz auction.

6.14 We also received a submission from BT/EE on 19 November in the form of an Economist Incorporated report which proposes a “relocation cost-based” assignment stage, among other options, to defragment the 3.4-3.8 GHz band through the auction. We have published this submission alongside this consultation.¹⁸³

Our provisional assessment

Mandatory reassignment

- 6.15 We do not consider mandatory reassignment to be a feasible route to defragmentation of this band.
- 6.16 To give effect to such proposals would mean reassigning some or all of the 3.4-3.8 GHz frequencies which have already been allocated. The rights to use those frequencies are set out in the wireless telegraphy licences issued at the end of the 3.4-3.6 GHz auction, and in UK Broadband’s licences which were awarded previously.
- 6.17 This would be a very significant amendment to the frequency usage rights that they would have previously held. We consider that significant changes such as those suggested by the MNOs to the licences could amount to a revocation of the existing licences and the issue of new licences.
- 6.18 In that event, absent the consent of the licensee(s), our power to revoke the existing licences of spectrum in the 3.4-3.8 GHz band (i.e. the 3.4-3.6 GHz licences that we awarded in April 2018 and the UK Broadband licences) is subject to limitations written into those licences.
- 6.19 In particular, our power to revoke these licences for spectrum management reasons is subject to a 5-year written notice period and, in the case of the 3.4-3.6 GHz licences that we awarded in the last auction, such notice may not be given before 15 years from the date of issue of the licence (i.e. not before April 2033, so any revocation would not take effect until April 2038).
- 6.20 We also note that a mandatory reassignment would have to take into account any further relevant considerations, including the fact that two of the bidders in the previous auction paid significant sums to secure specific frequencies, and these sums have been paid into the appropriate Consolidated Fund in accordance with the 2003 Act.

¹⁸³ https://www.ofcom.org.uk/data/assets/pdf_file/0008/130112/Submission-BT-EE-defragmentation-Economists-Incorporated-Report.pdf

Voluntary reassignment

- 6.21 A voluntary full band (3.4-3.8 GHz) assignment stage might result in contiguous spectrum holdings for all operators – but most likely only if all holders of spectrum in the 3.4-3.8 GHz band took part and their existing spectrum holdings were included in the pool of spectrum to be assigned. In particular, H3G would have to move at least some of its holdings.
- 6.22 We have therefore also considered whether we could make H3G’s participation in the award conditional on it including some (or all) of its existing spectrum holdings in the assignment stage of that award.
- 6.23 Even if such a condition of participation in the award could be justified, there is no certainty that H3G would enter the award on these terms. The value that H3G places on winning new spectrum in the award or consolidating its holdings in the 3.4-3.8 GHz band into a single contiguous assignment may be less than the value it places on being able to engage in trading using its existing licences (see the further discussion below about H3G’s incentives to trade). Unlike trading, a full-band assignment stage would not allow bidders to make payments to each other to incentivise participation in any process to defragment the entire 3.4-3.8 GHz band. Considered together with any cost of moving its spectrum holdings (or payment it may need to make to retain as far as possible its current frequencies), we consider that H3G may not have sufficient incentive to take part.
- 6.24 Without H3G’s participation, it is not clear that all or any of the remaining MNOs would necessarily choose to take part in a full band assignment stage. Even if each of BT/EE, O2 and Vodafone opted in, there is a limit to the extent of defragmentation that could be achieved. We therefore do not think a full band assignment stage is likely to be significantly more effective than post-auction trading among the winning bidders.
- 6.25 Finally, we also note that the design and implementation of a full band assignment stage could be complex given the number of possible assignment options.

Reassignment based on relocation costs

- 6.26 BT/EE’s submission from 19 November outlined a ‘relocation cost-based assignment stage’, as an alternative to conventional assignment stage bidding. In summary, this approach would involve operators with incumbent spectrum in the 3.4-3.8 GHz band agreeing to include their spectrum in a full band assignment stage. Ofcom and the operators would also agree on a cost-based model that specifies the relocation costs associated with different possible contiguous assignments across the 3.4-3.8 GHz band for the incumbents. The winning band plan would be the one that minimises relocation costs as a whole across bidders. Each winning bidder would then receive a discount on the amount it owed at the end of the principal stage to cover its relocation costs if the bidder had to move frequencies. As the submission notes, and as set out in section 7, Ofcom does not have the power to make payments to bidders from the auction. Therefore, in practice, any discount would be limited to the amount each owed at the end of the principal stage (which could be zero, if a relevant operator had not won any spectrum in the principal stage).

- 6.27 However, as with the voluntary assignment stage option, we note that this relocation cost-based approach is only likely to achieve defragmentation of the entire 3.4-3.8 GHz band if all holders of 3.4-3.8 GHz spectrum took part. For the same reasons as above, we consider that H3G may not have sufficient incentive to take part in any such process. H3G may place more value on being able to engage in trading using its existing licences than the discount that it may receive through the relocation cost-based assignment stage.

Other approaches to full band assignment

- 6.28 BT/EE's submission included alternatives to the relocation cost-based model in order to achieve contiguous assignments across the 3.4-3.8 GHz band. The first would involve all bidders voluntarily putting their existing 3.4-3.8 GHz holding into the assignment stage and have bidding taking place with tokens instead of money. The submission claimed that this would ensure contiguous assignments for all bidders, without bidders having to pay excessive prices in the assignment stage. In this scenario, bidders would not be compensated for re-locating their existing holdings. For the same reasons as above, we consider that H3G may not have sufficient incentive to take part in any such process.
- 6.29 The second alternative in the report would be to allow negative bids in the assignment stage, potentially using a first price rule. This would allow incumbents to receive a discount on their principal stage bids. This may give H3G greater incentives to include their current holdings into the assignment stage, as they could receive a discount which is larger than their relocation costs. However, the report highlighted that there were a number of complexities with this approach that could also be distortionary and subject to gaming. As noted above, Ofcom does not have the power to make payments to bidders from the auction, which would limit the discount that any bidder could achieve to the amount it owes (if any) at the end of the principal stage. For these reasons we consider that post-auction trading among bidders is likely to be the more effective approach.

Post auction trading

- 6.30 We have considered whether defragmentation could be achieved through spectrum trading. Clearly, this would be possible if all relevant licensees in the 3.4-3.8 GHz band perceived an advantage in engaging in such trades.
- 6.31 Defragmentation could be delivered for all MNOs through relatively simple bilateral trades. For example, it would require only two separate bilateral trades to achieve defragmentation in a number of reasonably likely outcomes to the principal stage of the 3.6-3.8 GHz auction.
- 6.32 Depending on the outcome of the auction, some MNOs with separate blocks in the 3.4-3.6 GHz and 3.6-3.8 GHz frequencies might be able to achieve a contiguous holding through post-auction trades without H3G's involvement. However, H3G's participation in any post auction process would be essential for all of the MNOs to achieve contiguity of their spectrum holdings in the 3.4-3.8 GHz band.

- 6.33 We believe H3G does have incentives to engage in trading.¹⁸⁴ This is because there are likely to be benefits from wider defragmentation of the band, and H3G will only be able to profit from this if it trades its current location in the 3.4 GHz band.
- 6.34 To the extent that the gains to other operators from obtaining contiguous spectrum are significant, they would be able to provide an incentive for H3G to sell or move its 40 MHz holding (3460-3400 MHz). H3G would have an incentive to trade in order to share in these gains.
- 6.35 We believe H3G may also have incentives to trade its 3.4 GHz holdings for spectrum in other bands. Whilst H3G has a strong position in relation to 3.4-3.8 GHz spectrum, it does not have such an advantage in relation to spectrum bands which are useful for other aspects of a mobile operators' competitive offering.
- 6.36 For example, H3G currently holds very little sub-1 GHz spectrum (just 10 MHz of 800 MHz spectrum, which is less than 10% of all currently allocated sub-1 GHz spectrum). H3G may have an incentive to trade its 3.4 GHz holdings to gain access to some more low frequency spectrum.
- 6.37 In relation to its incentives to trade, H3G has written to us confirming its willingness to trade has not decreased as a result of our decision to vary its 3.6GHz licence.¹⁸⁵

Provisional conclusion

- 6.38 Having considered the options available to us for facilitating defragmentation of the 3.6-3.8 GHz band in this award, our provisional view is that the most effective approach is likely to be to allow the market to determine the best allocation of spectrum - first through the 700 MHz and 3.6-3.8 GHz auction and then through spectrum trading.¹⁸⁶
- 6.39 We recognise that there may well be benefits associated with defragmentation of the wider 3.4-3.8 GHz band. We would therefore expect to look favourably on any trades which supported defragmentation of the band, provided they did not give rise to competition concerns.
- 6.40 We consider that such trades would be unlikely to give rise to such concerns, given the provisional conclusions we have reached in section 5 above on the need for competition measures in this award, and the measures we took to safeguard competition when we awarded the 3.4-3.6 GHz spectrum.¹⁸⁷
- 6.41 We have considered potential options to facilitate post-auction trades through the assignment stage of the auction (see below).

¹⁸⁴ <https://www.ofcom.org.uk/consultations-and-statements/category-2/variation-uk-broadbands-spectrum-access-licence-3.6-ghz>

¹⁸⁵ [REDACTED]

¹⁸⁶ [REDACTED]

¹⁸⁷ Ofcom Trading Guidance Notes, https://www.ofcom.org.uk/data/assets/pdf_file/0029/88337/Trading-guidance-doc-jul15v0-1-2.pdf

Options to facilitate post-auction trades through the assignment stage

- 6.42 Our proposed auction design as set out in section 7 involves an assignment stage consisting of a single round of sealed bids, which enables bidders to express a preference as to the precise frequencies they will be allocated. We recognise that a bidder may wish to achieve an assignment in the 3.6-3.8 GHz band which complements their existing spectrum holdings and/or facilitates post auction trades.
- 6.43 We describe below some different forms of assignment stage which might go further than the form of assignment stage we are proposing.

Option 1: Restrict the assignment of any bidder who wins a small amount of spectrum to either the top or the bottom of the band

- 6.44 We expect that bidders are likely to be interested in winning at least 20 MHz in the 3.6-3.8 GHz band, and may engage in post-auction trades in order to achieve contiguous assignments across the wider 3.4-3.8 GHz band. We recognise post-auction trades to achieve defragmentation of the band may be impeded if a bidder who wins a small amount of spectrum (e.g. 5-15 MHz) ends up with that allocation being located between two other bidders who win more spectrum. These two bidders may otherwise have been able to trade with each other more easily to achieve contiguous assignments across the 3.4-3.8 GHz band.
- 6.45 We have therefore considered whether it would be appropriate to restrict the assignment stage options of any such winner of a small spectrum block to the top or the bottom of the band. The purpose of such a rule would be to facilitate any bidders who win at least 20 MHz to achieve assignments next to each other, such that they may more easily engage in trades to achieve contiguity of their spectrum holdings after the auction.
- 6.46 If we were to restrict bidders' assignment stage options in this way, we think it would be appropriate to allow any restricted bidder to bid on both the bottom and the top of the band. We would also allow bidders that have won 20 MHz or more to express their value for assignments at the top or bottom of the band. We note such bidders might have a higher intrinsic value for the bottom of the band than bidders that have won a small amount of spectrum. For example, this might be due to the maximum frequency span supported by antenna systems. Some bidders might also have a higher value for the bottom of the band than the top because there may be some relatively minor deployment restrictions until end of 2022 in the top of the band, due to the remaining existing user.
- 6.47 However, one potential drawback to this approach is that it may deny bidders their preferred location, even if they have the highest value for it. This would not just apply to bidders that win a small amount of spectrum, but may also apply to any bidders that acquire more than 20 MHz. For example, this restriction would arise if there were two bidders that had won more than 20 MHz, each of which bid a high value for the top and bottom of the band respectively, but there was also a third bidder that had won less than

20 MHz. In this scenario, only one of these two bidders could be allocated their preferred location, even if they had the highest value for it, due to the requirement that the third bidder must be located at either end of the band. This approach would therefore be restrictive on all bidders, not just bidders that win small amounts of spectrum.

Option 2: Bidders agree their assignments on a commercial basis, as a possible alternative to the assignment stage

- 6.48 Another option would be to allow bidders to negotiate their assignments in 3.6-3.8 GHz between themselves and keep assignment stage bidding as a fall-back option.¹⁸⁸ This would have the benefit of allowing bidders to negotiate any post-auction trades to defragment the wider 3.4-3.8 GHz band at the same time as agreeing their individual assignments in 3.6-3.8 GHz.
- 6.49 We envisage that this would work by allowing a window of time after the principal stage, where winning principal stage bidders could negotiate their assignments in the 3.6-3.8 GHz band, as well as any post-auction trades, on a commercial basis without Ofcom's involvement. If all principal stage winners reached a unanimous agreement during this period, we would proceed to award the 3.6-3.8 GHz frequencies in accordance with the agreement bidders had reached. If negotiations were unsuccessful, then assignment stage bidding would determine the frequencies.
- 6.50 These negotiations would necessarily involve the exchange of confidential information. In order to facilitate successful negotiations, our standard rules on confidential information would therefore not apply during this period (although bidders would have to ensure that negotiations were consistent with competition law).
- 6.51 Our preliminary view is that the time window for negotiations would need to be short, for example no longer than two weeks, to avoid causing a material delay to the outcome of the auction and Ofcom awarding the licences. To avoid any unnecessary delay, this option would only be triggered if all winning principal stage bidders opted in to the negotiation period, following the release of the principal stage results.
- 6.52 We have considered two approaches for when this negotiation window could fall:
- a) After the principal stage outcome, but before assignment stage bidding.
 - b) After assignment stage bidding, but before bids have been processed.
- 6.53 There are significant risks associated with the first approach. If the negotiations failed and the auction ended up proceeding to the assignment stage, bidders may be able to use confidential information gathered during the negotiation window to engage in strategic bidding, such as tacit collusion or bidding to disadvantage another bidder. For example, bidders may be able to coordinate to force another bidder into a position that would put

¹⁸⁸ The assignment of 700 MHz spectrum would be determined through the usual process of assignment stage bidding, and so would be out of scope for these negotiations.

them at a disadvantage for post-auction trading. Our provisional view is that this approach is therefore unlikely to be feasible.

- 6.54 The second approach removes the risk that bidders could use confidential information to distort the outcome of the assignment stage if negotiations fail, as assignment stage bidding would already have taken place. This approach would involve proceeding with assignment stage bidding shortly after the principal stage as usual.
- 6.55 However, rather than immediately processing the assignment stage bids and releasing the results to bidders, we would allow bidders the opportunity to agree their assignments (and, provisionally, any post auction trades) between themselves as alternatives to their bids. If the negotiations were successful, the bids submitted during the assignment stage would be void and would remain confidential. If unsuccessful, the final assignments and prices would be determined by the bids submitted in the assignment stage.
- 6.56 We are uncertain about the practicalities of allowing for a negotiation period between bidders to agree assignments. We consider that the period for negotiations would need to be fixed in the auction regulations so as to provide certainty (and a definite end-point for the auction). As noted above, the period should be short, so as not to cause a material delay to determining the outcome of the award and Ofcom awarding the licences. We would therefore be interested in stakeholders' views on the likely feasibility of such negotiations being successfully concluded in a short period, such as two weeks.
- 6.57 We would also be concerned if, despite standard rules on confidential information being disapplied during this period, the nature of discussions required for successful negotiations could result in any other reason for bidders being at risk of disqualification (and/or forfeiture of deposits made) from the award process in light of the auction rules.
- 6.58 We are therefore interested in stakeholders' views on the substantive and practical implications of this option, including the likelihood of successful negotiations and the length of time it may take to reach an agreement.

Option 3: Contingent bidding in the assignment stage

- 6.59 We have also considered whether we could allow bidders to make assignment stage bids contingent upon the identity of who would hold any adjacent spectrum, as an alternative to a conventional assignment stage where bidders bid only on their possible allocations.
- 6.60 This would theoretically have the benefit of allowing bidders who wish to trade with each other (and therefore have a mutually high value for adjacent assignments) to reflect this in their bids.
- 6.61 For example, if bidder A wished to engage in a post-auction trade with bidder C and, to a lesser extent, with bidder D, bidder A could make a bid of:
- a) £x for the specific frequencies subject to bidder C winning rights to use frequencies adjacent to it; and
 - b) £y for those same specific frequencies subject to bidder D winning rights to use frequencies adjacent to it, which would be a lower value than £x.

- 6.62 The introduction of contingent bids would make bidder choices more complex in the assignment stage. Bidders would have more options to consider, and potentially a large number of options if they were interested in trading with different bidders.
- 6.63 Bidders may also not have the same view on who their preferred ‘neighbour’ would be, and so may end up bidding against each other. Additionally, there may be scope for strategic bids to disadvantage competitors. Contingent bids would also make the winner determination and pricing algorithm more complex, and make it more difficult for bidders to develop bidding strategies.
- 6.64 A similar option to this would be to allow bidders to bid on the entire band plan for the 3.6-3.8 GHz band. This would mean bidders could bid on the location of all winning principal stage bidders.
- 6.65 However, there are downsides to allowing bids on the position of bidders other than immediate neighbours. For example, there is more scope for a bidder to try to force competitors it has no interest in being next to into positions that may weaken them.

We provisionally propose to proceed with a conventional assignment stage

- 6.66 We consider that all of the options we have explored above could potentially facilitate defragmentation of the 3.4-3.8 GHz band, and therefore might help to realise the potential associated benefits for consumers. These options could be implemented in isolation, or in combination with each other in order to maximise the chances of successful post-auction trades to address defragmentation.
- 6.67 Our view is that allowing a negotiation window after assignment stage bidding may be the most straightforward option for facilitating post auction trades through the auction, without introducing potentially material implementation or bidding complexity.
- 6.68 However, as set out above, there are downsides to each of these options such as potentially: restricting the possible assignment stage outcomes, causing a delay to the outcome of the auction, and increasing scope of strategic bidding in the assignment stage. We are also uncertain about the level of bidders’ interest for any of these options.
- 6.69 In light of this, we are currently minded to proceed with a conventional assignment stage for this auction. However, we welcome feedback from stakeholders on the options we have outlined above to inform our view on the potential demand for these options, including any comments on ways to mitigate the risks we have identified.

Consultation question

Question 4: Do you agree with our proposal to proceed with a conventional assignment stage?

7. Auction design

- 7.1 This section of the consultation sets out our proposals for the design of the 700 MHz and 3.6-3.8 GHz spectrum band auction and our supporting reasoning.

Summary of our auction design proposal

- 7.2 We have considered two auction formats for this award: the Simultaneous Multiple Round Ascending (SMRA) and the Combinatorial Clock Auction (CCA).
- 7.3 We have used both formats in the past, depending on which design we considered to be appropriate under the circumstances, including the nature of the demand for the spectrum on offer. In this award, one of our objectives is to improve mobile coverage through including coverage obligations, which is a key consideration in our auction design proposals.
- 7.4 For this award, we are proposing to use a CCA with freestanding coverage obligation lots which are not attached to specific spectrum.¹⁸⁹ This would allow bidders to ‘package’ the obligations with the particular spectrum that they want to bid for, rather than Ofcom deciding what spectrum the coverage obligations are attached to.
- 7.5 This may mitigate the risk of unsold obligations, as the sale of obligations will be less dependent on demand for a specific type of spectrum offered in the award. In turn, this potentially increases the pool of bidders who might be interested in taking on a coverage obligation. Furthermore, having the coverage obligations as freestanding lots will also mitigate the risk of spectrum going unsold.
- 7.6 Each coverage lot would have a negative reserve price, which can be viewed as a maximum discount that bidders can receive on their spectrum packages. This would ensure that coverage obligations are awarded only when they increase the total auction value.¹⁹⁰
- 7.7 We set out in annex 13 how we are proposing to set a maximum discount for the coverage lots in the range £300m-£400m, with a central case of £350m. The annex also explains the role of the maximum discount in the auction in more detail.
- 7.8 The auction should be designed to best achieve our objectives in this award, including securing optimal use of this spectrum in the interests of consumers and citizens. In addition, participants in the auction should have confidence in the fairness of the process and the final outcome. To achieve our objectives, we seek to incentivise straightforward bidding and to allow bidders to express their preferences as bidding progresses. We are therefore proposing to include a Final Price Cap and Relaxed Activity Rules in our design.

¹⁸⁹ We refer to the freestanding coverage obligations as “coverage lots” throughout this section. We note that bids on the coverage obligation(s) are to include a licence condition to deliver the coverage obligations as set out in section 4 in the award licences.

¹⁹⁰ ‘Total auction value’ means the value in the auction from a candidate combination, where all spectrum and coverage lots are allocated to bidders or to Ofcom, taking into account the bids and reserve prices.

7.9 These rules will make it easier for bidders to determine what packages they are more likely to win as the auction progresses, based on their valuations and budgets. Similar rules have been used in other auctions, such as in spectrum auctions in Canada and Ireland. These rules also address some of the feedback provided by bidders and the National Audit Office in respect of the UK 4G auction in 2013, which did not include a Final Price Cap or Relaxed Activity Rules.

7.10 In summary, our proposed auction design has the following features:

- **A principal stage and an assignment stage** – The auction would have two bidding stages: the principal stage and the assignment stage. The principal stage determines the amount of spectrum won and would have frequency generic lots. It comprises a series of ‘clock’ rounds with ascending prices and a final round of sealed bids, called the Supplementary Bids Round, with a second-price rule. The assignment stage determines the precise frequencies awarded, and would have a sealed-bid, single-round format with a second-price rule.
- **Spectrum lots** – We are proposing to offer three categories of spectrum lots:
 - 60 MHz in six lots of 2x5 MHz in the 700 MHz FDD spectrum, with a reserve price in the range of £100m-£240m per lot. These lots would have four eligibility points each.¹⁹¹
 - 20 MHz in four lots of 5 MHz 700 MHz Supplemental Downlink (SDL) spectrum, with a reserve price of £1m per lot. These lots would have one eligibility point each.
 - 120 MHz in 24 lots of 5 MHz TDD 3.6 GHz spectrum, with a reserve price in the range of £15m-£25m per lot. These lots would have one eligibility point each.
- **Coverage lots** – We are proposing one coverage lot category, which would have a negative reserve price that acts as a maximum discount on spectrum prices:
 - Two lots for each of the proposed coverage obligations with a maximum discount in the range of £300-400m. The coverage lots would have no eligibility points.
- **Positive price constraint** – Ofcom does not have the power to accept negative bids. We are therefore proposing that the minimum package price and bid amount would be £1,000. This means if a package price at the clock round prices is less than this amount (due to coverage discount being greater than the spectrum price in the package), the package price would automatically be converted to £1,000.
- **Relaxed Activity Rule** – To allow for straightforward bidding, we are proposing to adopt a hybrid eligibility point/revealed preference Relaxed Activity Rule. This would allow a bidder to bid for a package above its current eligibility if this was consistent with the preferences revealed by its previous clock stage bids and was below its initial eligibility level. A bid above current eligibility levels would be a relaxed bid and may require chain

¹⁹¹ Eligibility points are used in auctions to incentivise straightforward bidding. We explain eligibility points further from paragraph 7.154.

bids. Chain bids are additional bids that are submitted to maintain bidders' relative preferences between packages as round prices increase.

- **Relative Cap and Final Price Cap** – To further encourage straightforward bidding, we propose to include a Relative Cap that would only be created by eligibility reducing bids in the clock stage. In addition, we would apply a Final Price Cap, which would constrain the bids that can be placed in the Supplementary Bids Round relative to the bidder's package and the prices in the final clock round.
- **Information policy** – After the end of each clock round, other than the final clock round, we propose to inform bidders whether the level of excess demand for each spectrum lot category is less than or equal to the nearest higher multiple of 20 MHz (e.g. less than or equal to 20 MHz, less than or equal to 40 MHz etc.). We propose to reveal no aggregate demand information on the coverage lots after each clock round. We also propose to reveal no aggregate demand information after the final clock round.

7.11 We set out in annex 16 a detailed description of the auction procedures we are proposing. This annex aims at illustrating how our proposed CCA format would work in practice.

7.12 The rest of this section has the following structure:

- Stakeholders' comments on auction design in response to the March 2018 consultation
- Auction format considerations
- Coverage obligation considerations
- Description of proposed CCA rules
- Spectrum reserve prices

Stakeholders' comments on auction design in response to our March 2018 consultation

Initial views on auction design from the March 2018 consultation

7.13 Although we did not consult on auction design in our March 2018 consultation, we set out our initial views on how our auction could support coverage objectives using the 700 MHz spectrum.¹⁹²

7.14 For illustration, we set out that the coverage obligations could be pre-attached to 2x5 MHz of the paired 700 MHz FDD spectrum. A key benefit of pre-attaching the coverage obligations to 2x5 MHz of spectrum would be to maintain flexibility in the potential ways in which spectrum can be allocated to bidders in the auction. However, we recognised this may introduce some aggregation risk, in that bidders are unlikely to want to bid for a 2x5 MHz coverage lot on its own.¹⁹³

7.15 We also set out our concern that pre-attaching coverage obligations to spectrum could lead to coverage obligations and spectrum going unsold. These risks arise from the

¹⁹² "Improving mobile coverage", March 2018,

https://www.ofcom.org.uk/_data/assets/pdf_file/0022/111937/consultation-700mhz-coverage-obligations.pdf

¹⁹³ Aggregation risk occurs when a bidder values a combination of lots more than the sum of the values of the individual lots in that combination.

inherent uncertainty around operators' costs of deploying new coverage, and the uncertainty of the commercial value of spectrum to which the obligations may be pre-attached.

- 7.16 We noted that these risks are greater for this auction than for previous spectrum auctions, because our proposed coverage obligations were more ambitious than coverage obligations we have included in past auctions. We explained that it may be possible to tailor our auction design to mitigate this risk.
- 7.17 One such auction mechanism we suggested to mitigate the risk of unsold spectrum was an opt-in round. In this opt-in round, bidders would be asked to submit bids at the reserve price for a range of spectrum packages that include one or more coverage lots. The intention would be to ensure that, if there were demand for the coverage lots at the reserve price, then they would be sold in the auction.
- 7.18 If, on the other hand, there was insufficient demand in the opt-in round to sell all coverage lots at the reserve price, then the auction rules could be set so as to allow one of the geographic coverage lots to be converted into a 2x5 MHz lot without any coverage obligation attached. This would result in there being an additional 2x5 MHz lot of unencumbered, paired spectrum.
- 7.19 We also suggested 5 MHz lot sizes for the 700 MHz SDL spectrum.

Summary of responses relating to auction design

- 7.20 In response to the March 2018 consultation, we received comments from MNOs and others on our early views on auction design. The main themes from responses are summarised below.

Sequential auction including a reverse auction stage

- 7.21 Three of the four mobile operators (O2, BT/EE, and Vodafone) suggested that we separate the award of spectrum and coverage obligations into separate, sequential stages. They suggested that pre-attaching the obligations to 700 MHz FDD spectrum may distort auction outcomes or prices for spectrum. These operators preferred an alternative approach in which we would first award the spectrum free of obligations, followed by a 'reverse auction' for the coverage obligations.
- 7.22 In this reverse auction, bidders would compete for a discount on their spectrum fee in exchange for coverage obligations. O2 suggested that participating in this separate bidding stage could be open to any bidder with sub 1 GHz spectrum. It claimed this would ensure the coverage obligations are awarded to the operators that could implement them most effectively, rather than awarding obligations only to winners of 700 MHz FDD spectrum.
- 7.23 The IET also suggested a reverse auction for coverage obligations. This would entail a reverse auction against a specific list of site locations that would ensure mobile coverage of all major roads in the UK.

Joint bidding

- 7.24 Some respondents also suggested that we consider allowing bidders to bid jointly. O2 said we should consider allowing winning bidders in the 700 MHz FDD spectrum to bid jointly in the assignment stage, to facilitate future trading and/or network or spectrum sharing arrangements. It also suggested allowing joint bidding for the coverage obligations, noting that it may be more efficient for multiple operators to take on an obligation jointly. [REDACTED].

Auction format

- 7.25 O2 expressed a preference for a non-combinatorial, multiple round format, such as the SMRA auction format, as used in the 2018 auction of 2.3 and 3.4 GHz spectrum. O2 said combinatorial auction formats, such as the CCA, can be challenging for bidders with respect to internal governance.

Ofcom's response to stakeholders' comments

- 7.26 We have considered all comments in developing our auction design proposals. In particular, we have considered the risks raised by operators that arise from pre-attaching the coverage obligations to specific spectrum lots. We consider further the MNOs' proposal for a sequential auction below, where we discuss how we propose to include the coverage obligations in the auction.
- 7.27 In relation to joint bidding, we first discuss the possibility in the principal stage and thereafter in the assignment stage.
- 7.28 We note that joint bidding in the *principal* stage for coverage obligations would introduce significant opportunities for collusive behaviours between bidders. For example, joint-bidding might make it easier for bidders to engage in strategic investment to foreclose other operators from acquiring spectrum in the auction, distorting the outcome of the award. This could negatively impact competition in the market.
- 7.29 Furthermore, allowing the bids or outcomes of bidding partners to be conditional upon each would add considerable complexity to the auction rules and software. It is also likely that bidders would not want to bid jointly for all three types of spectrum in the award. It would be problematic to allow bidders to jointly bid for some lots, but separately for other lots.
- 7.30 We recognise that allowing joint bidding in the *assignment* stage may facilitate network or spectrum sharing, or trading arrangements between bidders following the auction.¹⁹⁴ We specifically discuss options to facilitate post-auction trading in section 6 of this consultation in the context of 3.4-3.8 GHz defragmentation.

¹⁹⁴ Spectrum sharing is not a new consideration for this award. This was also discussed in a UK 4G auction consultation, "Second consultation on assessment of future mobile competition and proposals for the award of 800 MHz and 2.6 GHz spectrum and related issues", https://www.ofcom.org.uk/data/assets/pdf_file/0025/55276/combined-award-2.pdf, from paragraph 7.78.

- 7.31 While there are still strategic opportunities for joint-bidders in the assignment stage, the impact of strategic bidding is likely to be less than in the principal stage, as bidders can only influence the precise frequencies awarded rather than the amount of spectrum won. One way that joint-bidding could work is by giving winning principal stage bidders the opportunity to agree joint bidding vehicles (JBVs) amongst themselves, between the principal and assignment stages.
- 7.32 However, there are still material challenges to joint-bidding in the assignment stage, including the potential for anti-competitive consequences to arise as a result of bidders' JBV negotiations. There is also the likelihood that negotiations will be unsuccessful and therefore cause an unnecessary delay to the outcome of the award. On balance, we do not consider that joint bidding in the assignment stage would be appropriate in this auction.

Auction format considerations

- 7.33 We have considered a range of potential formats for the principal stage of the auction. We narrowed these down to two – a combinatorial clock auction (CCA) and a simultaneous multiple round ascending (SMRA) auction with generic lots.
- 7.34 We are not convinced of the benefits of alternative auction formats for this award. The SMRA and the CCA are well-understood and widely tested formats commonly used for spectrum auctions. We have successfully used both for previous spectrum awards in the UK and they have been used frequently in Europe in recent multi-band auctions.
- 7.35 Both formats would follow the same stages, although the mechanics of the principal stages would be different. The design of the assignment stage would be the same for the SMRA and CCA.

Figure 7.1: Outline of the stages of each auction format

Auction stages	Application	Qualification	Principal	Assignment	Grant
SMRA	Application	Qualification	Primary rounds	Assignment stage	Licence granted
CCA	Application	Qualification	1. Clock rounds 2. Supplementary Bids Round	Assignment stage	Licence granted

Generic lots

- 7.36 Regardless of whether the format were an SMRA or CCA, the principal stage would involve generic spectrum lots. This means that bids in the principal stage would not relate to specific frequencies, but to lots of specified bandwidths with unspecified frequencies. Bidders who have won generic spectrum lots in the principal stage can bid to determine the exact location of their frequencies in the assignment stage.
- 7.37 Generic lots minimise the risk of fragmentation of the auctioned spectrum, i.e. they aid contiguity of assignments in the 700 MHz and 3.6-3.8 GHz bands. Using a generic lot stage allows simplicity of bidding, encourages a speedier auction and is more flexible than a frequency-specific auction with a single bidding stage. A generic principal stage also reduces the opportunity for strategic bidding aimed at splitting a competitor's assignment of auctioned spectrum.
- 7.38 Awarding generic lots in the principal stage requires a subsequent assignment stage to allow bidders to express a preference for a particular part of the band.

Strategic bidding

- 7.39 In developing our auction design proposals, we have considered the potential for strategic bidding. The main categories of strategic bidding we have considered in this auction are:
- Strategic investment – bids in excess of a bidder's own intrinsic value for an amount of spectrum with the aim of denying that spectrum to competitors.
 - Price driving – a bidder places a bid above its intrinsic valuation for a spectrum package in order to raise the price paid by other bidders.
 - Tacit collusion – bidders jointly reduce demand to reduce the final prices that they must pay (which is sometimes referred to as market division).
 - Strategic demand reduction – a bidder reduces the number of lots they bid for in order to reduce their final price per lot.
 - Signalling – a bid that is intended to share information with another bidder, or suggest a bidding strategy to another bidder.

Simultaneous Multiple Round Ascending (SMRA) Auction

- 7.40 The SMRA is an open ascending auction for different lots of spectrum that takes place over a number of rounds. In this format, bids are placed for individual lots, in multiple lot categories, at the same time. The auction proceeds through successive rounds with increasing prices until there are no new bids. In between the rounds, bidders typically receive some information about the level of excess demand in the lot categories to help inform their bidding strategies.
- 7.41 A points-based activity rule is often used, under which bidders may only maintain or decrease their level of demand from one round to the other, as measured by the number of eligibility points. In each round, the highest bid placed on each lot is called a Standing High Bid. When the auction ends, Standing High Bids become winning bids and the bidders pay the amounts they bid. With generic lots, bidders are awarded a number of lots at the end of the principal stage of the auction, and then proceed to an assignment stage to determine the exact location of their frequencies.
- 7.42 Ofcom used an SMRA format in the 2018 auction of the 2.3 and 3.4 GHz bands. If we were to use the SMRA format for the forthcoming award of 700 MHz and 3.6-3.8 GHz, we would expect to use the specific design for the 2018 auction as the starting point. We would then consider how to best incorporate the coverage obligations into the auction design.
- 7.43 The SMRA format has also been widely used in recent spectrum multi-band awards, including in the United States, Germany, Spain, Norway, Sweden and Finland.

Combinatorial Clock Auction (CCA)

- 7.44 In a CCA format, bids are submitted for packages of lots, not for individual lots. Bidders are either awarded a package of lots for which they bid in its entirety or nothing at all. This differs from the SMRA, in which a bidder submits bids for a number of individual lots, and there is the possibility of it winning fewer lots than it bid for.
- 7.45 Throughout a CCA auction, bidders submit multiple package bids that are mutually exclusive, meaning that only one bid from each bidder may win.
- 7.46 The principal stage of the CCA is a two-phased bidding process for different lots of spectrum:
- a) The first phase is known as the Primary Bid Rounds and features a number of 'clock rounds'. In this phase, bidders place bids for a number of lots in each category. The price of each bidder's package bid is determined by the prices for each lot category set by the auctioneer (i.e. Ofcom) at the start of each round. The auction proceeds in successive rounds, during which the price increases for generic lot categories in which there is excess demand. The clock rounds end when there is no excess demand for any lot category. A points-based activity rule similar to the one described for the SMRA has been commonly used in the clock rounds, although there are alternative approaches that can provide additional flexibility during the clock rounds (as explained below).

- b) The second phase is called the Supplementary Bids Round and is a single-round sealed-bid process where bidders may submit bids, subject to constraints, for the packages they bid on during the clock rounds and may also place new bids for other packages. The constraints that apply are designed to ensure that a bidder's bids are consistent with preferences revealed in the bids submitted in the clock rounds. Many mutually exclusive bids can be placed in the Supplementary Bids Round.¹⁹⁵
- 7.47 At the end of the Supplementary Bids Round, all bids placed in both the clock rounds and the Supplementary Bids Round are considered in order to determine the outcome. The process to decide the outcome is called the 'winner determination'. The combination of bids that maximises the total value, subject to a maximum of one bid from each bidder, is selected. Bids included in that combination are winning bids.
- 7.48 A 'base price' for each winning bid is calculated according to a second price rule, which reflects the highest losing bid (or opportunity cost).¹⁹⁶ This is different to the SMRA where bidders pay the amount that they bid for the lots that they win (a 'pay as bid' price rule).
- 7.49 As with the SMRA, these two phases will be followed by an assignment stage to determine the exact frequencies of the spectrum to be awarded to each successful bidder.
- 7.50 The CCA has been used by Ofcom before, including in the UK 4G auction (for 800 MHz and 2.6 GHz spectrum), although in different circumstances, as discussed below. The CCA format has also been widely used elsewhere in recent multi-band spectrum awards, including in Switzerland, Netherlands, Canada, Ireland, Austria, Slovakia and Slovenia.
- 7.51 We have considered enhancements to the detail of the CCA design which apply some of the lessons learned from the 2013 auction. These take account of feedback we received from stakeholders and the National Audit Office report "4G radio spectrum auction: lessons learned".¹⁹⁷
- 7.52 The enhancements include changes to the activity rules which aim to make the final clock round more indicative of the final outcome of the auction - both in terms of allocation of spectrum and prices paid. This should contribute to more informative clock rounds and reduce the scope for unpredictability in the Supplementary Bids Round. The enhancements reduce the uncertainty associated with the second price rule, which should lessen both the potential for surprise outcomes and the challenges faced by budget-constrained bidders.
- 7.53 Certain aspects of the UK 4G auction do not feature in the proposed auction design for the forthcoming award. These are:
- dynamic spectrum reservation (spectrum floors);¹⁹⁸ and

¹⁹⁵ For example, bidders made the following numbers of bids in the Supplementary Bids Round of the UK 4G auction. Vodafone: 94, Niche (BT): 89, EE: 48, H3G: 17, Telefónica: 11, HKT: 9, MLL: 9.

¹⁹⁶ The second price rule requires bidders to pay an amount that is just sufficient to ensure that no other bidder or coalition of bidders was prepared to pay more for that package.

¹⁹⁷ Available at <http://www.nao.org.uk/wp-content/uploads/2015/03/4G-radio-spectrum-auction-lessons-learned.pdf>.

¹⁹⁸ The reserved spectrum was selected from a choice of specified alternative reserved spectrum packages, depending on the auction bids made both by bidders eligible to bid for reserved spectrum and by other bidders.

- competition between those bidders wanting individual (standard-power) licences and those bidders wanting concurrent (low-power) licences in the 2.6 GHz band.

Pros and cons of SMRA and CCA formats

Potential advantages of an SMRA

Simplicity

- 7.54 The SMRA is intuitively simpler to understand and is often preferred, for this reason, by some bidders. However, this does not mean that bidding in the SMRA is necessarily simpler, given some of the risks to bidders set out later in this sub-section.

No surprise outcomes

- 7.55 In the SMRA, bidders have a large degree of certainty when they submit their bids. This is, first, because the SMRA is a pay as bid auction, meaning that if the bid they submit is chosen as a winning bid, then they will pay the bid price for each lot they have won. Second, if the bidder is outbid on the spectrum, then the bidder will have an opportunity to bid back again in the next round at a higher round price to try to win the spectrum they most want at the current prices.

Budget constrained bidders have clearer information on prices they would pay

- 7.56 The certainty of prices that would be paid for winning bids in each round of the SMRA is helpful for budget-constrained bidders as they can continue to bid on their most preferred set of lots until the price exceeds their budget, even if not their underlying valuation. At this point, the budget-constrained bidder could switch to bidding on its next preferred set of lots that is still within its budget.

Potential disadvantages of an SMRA

Aggregation risk

- 7.57 Aggregation risk occurs when a bidder values a combination of lots more than the sum of the values of the individual lots in the same combination. This is a common feature in spectrum auctions, for instance if there are synergies in block sizes (e.g. a bidder may consider that a 2x10 MHz block is worth more than double a 2x5 MHz block).
- 7.58 In an SMRA, there is the risk that bidders end up winning a smaller amount of spectrum than they bid on. This creates risks for bidders to manage in their bidding decisions.
- 7.59 Taking the possible synergy in block sizes as an example, a bidder may ideally want to bid a higher per-MHz value for a 2x10 MHz block than for a 2x5 MHz block. However, the SMRA does not allow it to make a package bid on the 2x10 MHz block. The bidder therefore has to make a choice between imperfect alternatives.
- 7.60 For example, if a bidder bids for 2x10 MHz at its full value, then it risks only winning a smaller amount of spectrum, 2x5 MHz, which is not attractive to the bidder at the price it

must pay. On the other hand, if it bids less than its full value, it may reduce its chances of winning the 2x10 MHz spectrum block in the auction. There are potential mitigations for this (for example, the minimum requirement rule we used for our 2018 auction of the 2.3 GHz and 3.4 GHz bands), but these are imperfect.

Substitution risk

- 7.61 Due to the Standing High Bid mechanism, an SMRA has the risk that bidders are unable to move their demand across different lots of spectrum in response to changes in relative prices, if bidders view different lots of spectrum as substitutes.
- 7.62 An example of this is if a bidder started bidding on 2x10 MHz of 700 MHz FDD spectrum (with no coverage obligations) but, due to a price rise, wanted to switch to a 2x10 MHz lot with a coverage obligation attached. The bidder may end up in a situation where it is currently winning part of its initial bid on 2x5 MHz, without enough eligibility points to transfer its demand over to the 2x10 MHz coverage lot. There are ways to mitigate this risk in an SMRA, such as withdrawals, but they all have downsides.

Increased risk of strategic demand reduction

- 7.63 In an SMRA with a relatively small number of bidders (as is generally the case in spectrum auctions), the quantity demanded by bidders is likely to affect the price they would need to pay. Instead of competing for a large amount of spectrum, a bidder may anticipate the effect their bids have in raising the price, and instead seek to win a smaller amount of spectrum at a lower price, earlier in the process.
- 7.64 Bidders would have an incentive to do this if they believed they could achieve a larger profit from paying a lower price for a smaller amount of spectrum, rather than competing for a larger amount of spectrum, which would result in higher prices. This is different to collusion as bidders can find it profitable to do this unilaterally even without agreeing to reduce demand together – in other words, a bidder can be better off by simply reducing its own demand.
- 7.65 There is a risk to efficiency in the auction if a bidder who values the spectrum the most contracts demand and wins a smaller amount of spectrum than would be efficient.

Increased risk of tacit collusion

- 7.66 An issue that can arise in auctions is tacit collusion between bidders. This is where several bidders jointly reduce demand to reduce the final prices that they must pay (which is sometimes referred to as market division). This could impact on efficiency if individual bidders end up winning less or more spectrum than they would otherwise, based on their relative valuations.
- 7.67 This risk is more prominent in an SMRA. It is usually individually profitable for a bidder to deviate from a tacitly collusive outcome if other bidders cannot retaliate. However, in the SMRA there is the opportunity to bid back, which provides for the credible threat of a punishment mechanism to enforce the tacit collusion.

7.68 In addition, bidders can use bids to signal to each other more effectively in an SMRA, which would facilitate collusion. An example of signalling in an SMRA would be to use multiple waivers in order to show a contracting of demand to try and tacitly agree an allocation of spectrum.

Potential advantages of a CCA

Elimination of aggregation risk

7.69 In a CCA aggregation risk is eliminated due to package bidding, as a bidder either wins a package in its entirety or it does not win that package. In a CCA, a bidder cannot win only part of its package bid.

7.70 There are two forms of aggregation risk in this award, within and across lot categories:

- An example of within band aggregation could be in the 700 MHz FDD spectrum. We believe there to be synergies in that having a 2x10 MHz lot may be worth more than double a 2x5 MHz lot. This view is based on both technical considerations and evidence of EE's bids in the UK 4G auction for 800 MHz spectrum. A bidder in a CCA can express bids with a higher per-MHz value for a 2x10 MHz block than for a 2x5 MHz block to reflect its true values for these different block sizes and avoid the risk of only winning 2x5 MHz at too high a price.
- Aggregation risk could also be present between different lot categories. For example, a bidder may value 700 MHz spectrum more if it combines this with 3.6 GHz spectrum (and vice versa). We have not identified a strong basis for these types of cross-band synergies (other than in the case of a new mobile entrant), but it is possible.

7.71 There is a strong aggregation risk if there are specific coverage lots, which are not attached to any spectrum, and have a negative reserve price. If this is a suitable lot structure, the elimination of aggregation risk is a significant advantage of the CCA for this auction. We discuss this further from paragraph 7.92.

Elimination of substitution risk

7.72 CCA auctions allow bidders to express their valuations among all packages of spectrum, ensuring that there is no difficulty in switching between lots.

Decreased incentive to strategically reduce demand

7.73 Strategic demand reduction is not as prominent in a CCA as it is in an SMRA due to the second-price rule. This means that a bidder's price is set by the bids of others, rather than its own bids.¹⁹⁹ Therefore, a bidder can bid for both large and small package combinations, without the risk that it is raising its own price.

¹⁹⁹ In some instances, a bidder could affect their own price if there are core pricing adjustments.

Reduced risk of tacit collusion

- 7.74 The risk of tacit collusion is not eliminated in a CCA, but it is reduced relative to an SMRA. When a bidder submits additional bids in the Supplementary Bids Round of the CCA, it does not drive up its own prices (whereas the SMRA does not include a Supplementary Bids Round). This encourages the bidder to expand its demand to outbid its competitors for spectrum. There is also less of an opportunity for bidders to use signalling in a CCA (e.g. there are no waivers in a CCA).

Potential disadvantages of a CCAMore uncertainty on final outcome and prices

- 7.75 The Supplementary Bids Round of the CCA is a sealed bid round. Due to this, there is an element of unpredictability of the final outcome, which means that bidders can end up with a smaller amount of spectrum, or different packages, than they expected. Unlike the SMRA, there is no opportunity to bid back.
- 7.76 There can also be unpredictability in the prices paid for spectrum, as the second-price rule means that a winning bidder's price depends on the bids made by other bidders. It is also possible that the price for similar spectrum won by two or more bidders in the CCA may differ if underlying opportunity costs differ, which can be unexpected. This may be further compounded if some, but not all, bidders successfully engage in strategies aimed at pushing up the prices paid by their competitors. Significantly different prices for similar spectrum was not a feature of the outcome of the 2013 UK 4G auction, but it has been observed in a few CCAs in other countries.
- 7.77 The possibility of generating a surprise outcome is a concern to efficiency if it changes the way bidders bid and, as a consequence, they win less or more spectrum than they should win, based on their valuations.

Challenges for budget constrained bidders

- 7.78 Budget constrained bidders may face risks in their bidding decisions in a CCA, which can influence the package they win. In the CCA, bids indicate the maximum amount that a bidder is willing to pay for a package. However, the amount that they would actually have to pay if their bid wins can be much less than their bid amount due to the second price rule. Budget constrained bidders may therefore have to decide whether to risk making bids above their budget. They would do so with the expectation that they will most likely pay an amount equal to or below their budget if one of these bids won, but accepting the risk that they could pay a price up to the level of their bid.
- 7.79 If bidders are not willing to bid above their budget, then they will still have risks to manage. Budget-constrained bidders will need to decide whether to maximise their chances of winning larger packages (that have valuations above their budget) or smaller packages (that have valuations below their budget). For example, a bidder in a CCA may choose to bid up to its budget limit for a larger package, and reduce below its valuation the amount it bids for a smaller package (or choose not to bid for this smaller package at all). This could

preserve an incremental bid value between the larger and smaller packages that reflects the bidder's true difference in valuation between packages. This approach would maximise its chance of winning the larger package. However, it increases the risk that the bidder does not win any package.

- 7.80 Instead, the bidder may bid at or closer to its budget limit on the smaller package (or it may only place a bid on the smaller package). This reduces the probability of winning the larger package (by reducing the incremental bid value below its difference in valuation), but increases the chance that it wins a package (rather than nothing).
- 7.81 The strategic complexity caused by these concerns may have an impact on auction efficiency, if a bidder effectively ends up winning the 'incorrect' package.

Price driving

- 7.82 In both an SMRA and a CCA, bidders can place bids above their valuations for spectrum packages in order to increase the prices paid by other bidders. Under some circumstances, bidders may have more of an incentive to submit price driving bids in a CCA, compared to an SMRA. In part, this is because a bidder's final price in a CCA is unaffected by its own non-winning bids. In contrast, if a bidder submits bids for a larger number of lots than desired in an SMRA, and wins a smaller amount of lots, then they may increase their own final prices.
- 7.83 A potential mitigation against price driving, in either an SMRA or a CCA format, is to reveal less information about demand at the end of each round. Having less information about aggregate demand would make it more difficult for bidders to predict what packages their competitors are bidding on. This makes price driving bids more risky for a bidder to submit, given the increased possibility that it may have misjudged what its competitors are bidding on. We consider proposals for a limited information policy later in this section.

Coverage obligation considerations

- 7.84 As set out in section 4, we propose to offer two coverage obligations. Below, we discuss how we propose to implement our coverage proposals in terms of auction design.

Pre-attached coverage obligations

- 7.85 In many spectrum auctions with coverage obligations, obligations are attached to specific lots of spectrum; we call this 'pre-attaching' in this document. For example, in the UK 4G auction, there was one coverage obligation which was pre-attached to 2x10 MHz of 800 MHz spectrum.
- 7.86 When pre-attaching obligations, Ofcom would have to determine the band and amount of spectrum that each obligation was attached to. To attract bids to sell both coverage obligation lots, the value of the pre-attached spectrum must be greater than or equal to the cost of meeting the obligation for at least two bidders. If a lot remains unsold, then

that pre-attached spectrum would not be sold and that coverage obligation would not be fulfilled.

- 7.87 In our March 2018 consultation, for illustration, we said that coverage obligations could be pre-attached to 2x5 MHz of the 700 MHz FDD spectrum. We did not propose to attach obligations to the SDL spectrum due to the greater uncertainty in the value of this spectrum.
- 7.88 We have done some further thinking on how pre-attaching obligations could work in this auction, in light of our proposal to reduce the number of obligations from three (proposed in March 2018) to two (as set out in section 4 of this document).
- 7.89 We consider that pre-attaching obligations to lots of 3.6 GHz spectrum could result in a significant risk of spectrum going unsold, which may hinder early routes to 5G deployment. To mitigate that risk would require pre-attaching the obligations to a large block of 3.6 GHz spectrum, which would significantly reduce the unencumbered spectrum available and the flexibility of potential outcomes. We also now consider that pre-attaching the obligations to just 2x5 MHz of 700 MHz spectrum would similarly result in a significant risk of unsold spectrum, as well as coverage obligations going unsold.
- 7.90 If we considered it appropriate to pre-attach the proposed coverage obligations to any spectrum in the auction, our current view is that we would attach each of the two coverage obligations to 2x10 MHz of 700 MHz FDD spectrum. However, there are disadvantages to such a design:
- This would leave a small amount of unencumbered spectrum in the 700 MHz FDD band (only 2x10 MHz). The price of the unencumbered 2x10 MHz may therefore be distorted upwards, due to the reduced supply of unencumbered spectrum. This could change the allocation of 700 MHz FDD spectrum compared to a scenario where there were no pre-attached obligations.
 - There is a risk of failing to sell at least one of the two coverage obligations, either if:
 - the value of the pre-attached spectrum does not exceed the costs of meeting the coverage obligation for two bidders; or
 - bidders find it more profitable to bid for unencumbered spectrum.
 - Failing to sell a coverage lot would also mean that we would fail to sell the pre-attached spectrum.
- 7.91 Pre-attaching coverage obligations is possible in both the SMRA and CCA formats.

Unbundled coverage obligations

- 7.92 Another option is to unbundle the coverage obligations into separate lot categories, unattached to any spectrum. In terms of bidding and auction mechanics, the 'coverage lots' would operate in the same way as spectrum lots, but these lots would have negative reserve prices.

7.93 The negative reserve prices on the coverage lots can be viewed as a maximum discount that bidders can receive on their spectrum packages, if they are willing to take on a coverage obligation.²⁰⁰ A diagrammatic representation of spectrum lots in the three categories and coverage lots (labelled C) in a further lot category is shown below.

Figure 7.2: Overview of lot structure with unbundled coverage lots



7.94 If there is excess demand for the lots in a spectrum lot category, the price will increase in the next round. Similarly, if there is excess demand for the two lots in the coverage obligation lot category, in the next round the price will increase, i.e. become a smaller discount.

7.95 Separating out the coverage obligations has the following advantages:

- Bidders could choose the spectrum that they include alongside a coverage obligation. Bidders whose value of 2x10 MHz of 700 MHz spectrum is less than their cost of meeting an obligation can still bid for an obligation with more or different spectrum. Since bidders could bid for any combination of spectrum with a coverage obligation, this design would therefore allow operators to use the discount from taking on a coverage obligation to offset the price of 700 MHz FDD, 700 MHz SDL and 3.6-3.8 GHz spectrum. It may therefore increase the number of bidders who may be interested in bidding on the coverage obligations and reduce the risk of coverage obligations being unsold.
- There would be no risk of unsold spectrum due to the coverage obligations being too onerous. If bidders' costs of rolling out the coverage obligations are greater than the maximum discount available, then bidders could still bid on packages of spectrum without any coverage obligation. This would ensure that all the spectrum will be sold, regardless of whether the obligations are sold, provided the reserve prices on the spectrum are not set too high.
- All spectrum in the auction would be unencumbered, due to the coverage obligations being separate lots. This means that a bidder who does not wish to bid for coverage

²⁰⁰ We refer to 'packages' in the context of designs with unbundled coverage obligations as a combination of lots that a bidder is interested in, regardless of whether it is an SMRA or CCA format. This is different to a 'package bid' in a CCA, which refers to a bid for a 'package' of lots in a CCA, where a bidder is either awarded one of its package bids in its entirety or nothing at all.

could still bid for any and all spectrum in the auction. This would also mitigate the potential distortion to the price of 700 MHz FDD spectrum in the pre-attached design.

Positive price constraint

- 7.96 In some instances, adding a coverage obligation to a package of spectrum may cause the overall package price to be negative. Ofcom's power to make auction regulations is in respect of a process in which an applicant for a licence makes a bid specifying an amount that he is willing to pay to Ofcom in respect of the licence (see section 14 Wireless Telegraphy Act 2006). We also note that Ofcom is required under the Communications Act 2003 to pay auction receipts into the Consolidated Fund, and has no power to pay any part of those receipts to third parties, such as bidders in an auction.²⁰¹ We consider that in combination, these provisions mean that bids made in an auction must be in respect of net positive amounts and if a bid would otherwise be negative, the bid would have to be converted to a positive amount. In consequence, the minimum package price would have to be a positive amount.
- 7.97 We refer to these requirements that both the package bids and prices must be positive as the 'positive price constraint'. Our initial view is that £1,000 would be an appropriate minimum positive bid amount.
- 7.98 If the price of the spectrum a bidder has won is less than the discount for a coverage obligation, then the bidder would not be realising the full discount. In such circumstances, bidders may have an incentive to increase the amount of spectrum they are bidding on to increase their effective discount up to the full amount (or a large enough effective discount to offset their costs of the coverage obligation). This could result in a change in the allocation of spectrum compared to an auction with no coverage obligations.

Features of SMRA and CCA formats with unbundled coverage obligations

- 7.99 Given the positive price constraint, a consequence of unbundled coverage obligations is a very large aggregation risk for bidders.
- 7.100 We have considered whether unbundled obligations could work in an SMRA, given aggregation risk is more prominent in the SMRA format. Without any mitigations to address aggregation risk in an SMRA, bidders may be disincentivised from bidding on the coverage obligations at all, or regret bidding on coverage. For example, a bidder could end up winning a coverage obligation but with less spectrum than it originally bid for.²⁰² This may result in the bidder not winning enough spectrum to obtain a large enough effective

²⁰¹ We note that s14(5A) Wireless Telegraphy Act 2006 does allow Ofcom to make provisions for Ofcom to pay auction receipts to the holder of a surrendered spectrum licence. However, this provision does not apply here (because it is about a licensee surrendering spectrum into an auction in order to comply with a spectrum cap).

²⁰² An example of this would be a bidder bidding on a combination of spectrum lots and a coverage lot in round X, where it is made a standing high bidder on all the lots. In round X+1, the price of spectrum lots is increased and the bidder is outbid on some of the spectrum lots, but is still the standing high bidder on the coverage lot. The bidder is now only winning some of the spectrum lots it originally bid on and may find it unprofitable to re-bid on the spectrum lots.

discount to offset the cost of the obligation, as its spectrum package price is not large enough to realise the full discount on offer.

- 7.101 One potential mitigation for this would be to include a minimum spectrum price requirement with an automatic withdrawal rule on the coverage obligation in the SMRA. This would involve each bidder specifying before the start of the auction the minimum spectrum price that they would need to win in order to take on the coverage obligation. If a bidder's spectrum package price fell below its minimum spectrum price in any round, then its bid on coverage would be withdrawn without penalty.²⁰³
- 7.102 While this automatic withdrawal on coverage would mitigate aggregation risks in the SMRA, it may result in inefficient coverage outcomes. For example, suppose that there were three bidders competing for the two coverage lots at the start of the auction. The discount on the coverage lots would be bid down until there are only two bidders on coverage, i.e. the discount is no longer sufficient to cover the costs of the third bidder.
- 7.103 If spectrum prices continue to increase, these two bidders may end up contracting their demand on spectrum and falling below their minimum price requirement. This would therefore trigger their automatic withdrawal on the coverage obligations. In this scenario the coverage obligations will remain unsold.
- 7.104 However, if the third bidder ended up winning enough spectrum to cover its minimum price requirement, the more efficient outcome would have been for the third bidder to win a coverage obligation with a higher discount. In the example, this outcome would be possible under a CCA with unbundled obligations, but not in an SMRA.
- 7.105 While further mitigations may be possible, these all have their own risks. We also note that these mitigations for the SMRA would add significant complexity and may increase strategic bidding opportunities in the auction.
- 7.106 An important advantage of the CCA format is that it would eliminate the aggregation risk.
- 7.107 Even though the coverage lots have a negative price, the winner determination would work in the exact same way as a standard CCA. The winner determination works by analysing all the feasible combinations of bids with at most one bid from each bidder and determining which combination maximises value in the auction, subject to all lots being allocated.
- 7.108 In all CCAs, the reserve prices can be interpreted as 'bids' from the auctioneer and can be part of a combination, which would result in unsold lots (i.e. the lots are allocated to Ofcom) if these were part of the winning combination. We refer to this value of a combination of bids that includes both the bid values from bidders and Ofcom's reserve bids for unsold lots, if any, as the 'total auction value'. This winner determination calculation would therefore provide the mechanism by which we are able to not award a

²⁰³ We note that this rule would not be optimal in a SMRA due to the Standing High Bidder mechanics ensuring that a bidder is often winning less spectrum than they originally bid on. This rule would work better in a clock auction, which has very similar characteristics to the SMRA but avoids Standing High Bidder mechanics.

spectrum lot or a coverage obligation (see the examples set out in annex 13 for more detail).

- 7.109 We also note that it would be possible to have a mechanism in the auction to scale the level of coverage appropriately, rather than Ofcom pre-determining the exact level of the coverage obligation. For example, incremental coverage obligation scales can be included in bids as ‘add-on’ lots. The add-on lot would increase the level of geographic coverage by X%, which could only be bid on in conjunction with bidding on the lower level of coverage lot. However, we do not consider this further, since, as set out in section 4 and annex 12, we are not proposing a 92% geographic coverage option for this auction.

Role of the maximum discount

- 7.110 The maximum discount that would be set on the coverage obligations would serve two key purposes. These are:
- to provide an incentive for bidders to bid for the coverage obligations: and
 - to limit when a coverage obligation is awarded to reflect the balance between costs and benefits.

Providing an incentive for bidders to bid for the coverage obligations

- 7.111 A bidder will have its own assessment of the costs to it of meeting the coverage obligation. We would expect a bidder to compare its expected costs (net of any additional revenue it expects from increasing its mobile coverage due to the obligation) to the maximum discount available.²⁰⁴ If the discount outweighs the net costs, the bidder would be incentivised to bid on coverage, as they would make a profit.
- 7.112 If there is excess demand for the coverage lots, the discount would be competed down below the maximum level. We would expect a bidder to retain an incentive to bid for an obligation as long as the discount exceeds its (net) cost.

Limiting when a coverage obligation is awarded to reflect the balance between costs and benefits

- 7.113 We propose to set the maximum discount taking account of the benefits we expect from each coverage obligation. However, there are also costs to awarding the coverage obligation(s) which we expect to be reflected in auction bids. Firstly, the bidder will incur costs in meeting the obligation. Secondly, awarding a coverage obligation may involve a change in the allocation of spectrum, which is an opportunity cost.
- 7.114 Limiting when a coverage obligation is awarded would work better in the unbundled CCA due to package bidding. An example of the unbundled CCA limiting when a coverage obligation would be awarded would be if a bidder was only willing to take on the coverage obligation with a larger package of spectrum (e.g. due to the positive price constraint). We consider it desirable to award the coverage obligation unless the costs of doing so are larger than the benefits. The mechanics of the winner determination in a CCA would

²⁰⁴ When we refer to the cost of a coverage obligation, we mean the minimum compensation a bidder would need to be willing to bid for an obligation.

calculate whether a higher ‘total auction value’ is achieved by selling coverage obligation(s) or not, with the maximum discount reflecting the benefits and auction bids reflecting the costs.

- 7.115 The maximum discount would therefore restrict the degree to which the allocation of spectrum can change to accommodate awarding the coverage obligation to reflect the balance between obligation costs and benefits.
- 7.116 Annex 13 sets out a more in-depth explanation of the role of the maximum discount, and how we propose to set the level of the maximum discount in a way that seeks to ensure an appropriate balance between our estimate of the costs and benefits associated with awarding coverage obligations.
- 7.117 As set out in that annex, we propose to set the maximum discount for each of our two coverage obligations in the range of £300m-400m, with a central case of £350m.

Sequential auction

- 7.118 We have considered the suggestion from stakeholders that we separate bidding for spectrum and bidding for coverage obligations into two stages. This would entail an ascending auction for the spectrum stage, while the coverage obligation stage would be a separate descending (or reverse) auction involving free-standing ‘negative bids’ (i.e. discounts). Some stakeholders suggested that the first stage should be an SMRA.
- 7.119 The positive price constraint discussed above would still apply across both stages. This means that the discount that can be achieved by any bidder in the second stage to award coverage obligations is limited by the price of the spectrum it won in the first stage.
- 7.120 There are similarities as well as differences between a sequential auction and the auction with unbundled obligations described above. In both cases, the auction would be performing both a reverse auction for coverage obligations with descending prices and also an ascending auction for spectrum. In the sequential auction these two functions would be separated into different stages, whereas in an unbundled auction they would occur simultaneously.
- 7.121 Due to the similarities we believe that the sequential auction shares some of the same benefits as those outlined in the unbundled obligation case described above. A summary of these benefits is that:
- Bidders would win the obligation with the spectrum they want to win, rather than Ofcom deciding what spectrum the obligations are pre-attached to;
 - There would be no risk of unsold spectrum due to the coverage obligations;
 - All spectrum would be unencumbered.
- 7.122 Different auction formats could be used for either stage of the sequential auction. For example, the design for the first stage to award spectrum could be an SMRA or a CCA. Since the first stage would only include the three spectrum lot categories and no coverage obligations, this design could be a standard SMRA or CCA without pre-attached obligations

or negatively priced lots. The second stage of the auction could be a clock auction, second price sealed bid auction or another format.

- 7.123 In theory, it might be possible to allow for joint bidding on coverage obligations in a sequential auction. We do not think it would be desirable or practical to allow joint bidding on coverage in designs where we are awarding the coverage obligation and spectrum within the same bidding stage, as set out above from paragraph 7.27.
- 7.124 However, some of those concerns relate to simultaneous bidding for spectrum and coverage obligations, which would not apply in a sequential auction. We envisage that joint bidding on coverage could work, for example, by allowing bidders to form joint bidding vehicles (JBVs) just for the coverage stage of the auction. If successful, this would allow JBVs to share the cost of the obligation, which may in theory incentivise more bids on coverage.
- 7.125 However we note that there would still be significant risks and complications that result from joint bidding for coverage. For example, if bidders are allowed to form JBVs for coverage before the auction begins, we would need to be assured that any JBV discussions do not compromise the integrity of the auction, e.g. they do not involve exchanging confidential information on demand or value for spectrum, which could distort the outcome of the spectrum stage. Therefore, there remains a significant risk that many of the concerns about joint bidding discussed above would also arise in a sequential auction.
- 7.126 Alternatively, if we allow bidders to form JBVs between the spectrum and coverage stages, these agreements may be complex to agree and could cause a material delay to the completion of the auction. For example, in order to form a JBV, bidders may need to agree roll-out strategies, how to divide costs and bidding strategies. These negotiations may also simply fail.
- 7.127 There also remains a risk of compromising the integrity of the second stage of the auction, as bidders may be able to use the information gathered during the failed negotiations to bid strategically.
- 7.128 We therefore consider that, while a sequential auction has the benefit of theoretically allowing for joint-bidding, there are also risks of distortions and practical downsides which may mean that these benefits do not materialise in practice.
- 7.129 We consider that an unbundled auction has several advantages compared to a sequential auction. These arise from the upsides of awarding coverage obligations and spectrum simultaneously, compared to separating the two functions into sequential stages. These advantages are magnified the higher the maximum discount on coverage, relative to the final prices of spectrum. The advantages are:
- An unbundled auction addresses the aggregation risk that would occur in the sequential auction between the spectrum and reverse coverage stage. In the sequential auction, a bidder who requires more spectrum than it would otherwise to take on the coverage obligation has a difficult decision, as it will not know whether it is going to win a coverage obligation (and the associated 'discount') at the point at which

it has to decide how much spectrum it should bid for. The bidder could choose to: (i) not bid for more spectrum and not bid on coverage; (ii) bid for more spectrum and hope that they also win the coverage obligation for a large discount. Both options can have negative consequences on efficiency if the spectrum and/or coverage obligations are allocated to bidders with lower valuations.²⁰⁵

- If there are budget constrained bidders, there may be reduced competition on the spectrum in the sequential auction compared to an unbundled auction. In an unbundled auction, a budget constrained bidder could reduce the price it pays for spectrum and alleviate budget constraints, if it also wins a coverage obligation with the associated discount. However, in a sequential auction, a bidder bidding in the first stage would not know whether it would obtain a discount by winning a coverage obligation in the second stage. Or, even if it did win a coverage obligation, the bidder would not know when bidding in the first stage what size discount it would achieve in the second stage. This discount could be bid down significantly through excess demand for coverage obligations.
- In the sequential auction, there is a risk that bidders could strategically win more spectrum in the first stage in order to reduce competition for the coverage discount in the second stage. If a bidder is successful in following this strategy, this would reduce the final prices paid by other bidders in the first stage below the maximum discount in the second stage. The strategic intention would be to make it unprofitable for other bidders to bid on the coverage obligation (given the positive price constraint), enabling the strategic bidder to receive the maximum discount on offer rather than a lower amount.
- The costs or revenues of the coverage obligation may be affected by the allocation of spectrum, especially for a new entrant. For example, a bidder could find it cheaper to deliver the coverage obligation with more low frequency spectrum, i.e. the 700 MHz spectrum. There may therefore be an advantage for bidding on the spectrum and the coverage obligations at the same time instead of separate sequential bidding stages for some bidders.

7.130 On balance, we consider that an unbundled auction is likely to perform as least as well as a sequential auction in terms of achieving our objectives. Under some scenarios, an unbundled auction would perform better than the sequential auction in terms of incentivising bids on coverage e.g. if the positive price constraint is binding, such that bidders need to acquire more spectrum in order for bids on coverage to be profitable.

Provisional conclusion on auction format

7.131 There are advantages and disadvantages associated with both the CCA and SMRA formats. The relevance of these advantages and disadvantages can differ, depending on the precise circumstances of the award. We have used both formats for previous auctions. For

²⁰⁵ The bidder could choose to pursue option (ii) but fail to win the coverage obligation. This would cause there to be an inefficient allocation of spectrum, which could have been avoided had the bidder pursued option (i). Alternatively, the bidder could have pursued option (i), but they could have won the coverage obligation had they pursued option (ii).

example, we opted to use a CCA for the 4G auction in 2013, while we used an SMRA format for our most recent 2018 award of the 2.3 GHz and 3.4 GHz bands.

- 7.132 A key driver in the choice between formats for this auction are the coverage obligations, and which format best allows us to strike an appropriate balance between our objectives of ensuring efficient allocation of the spectrum and improving mobile coverage.
- 7.133 A significant advantage of the CCA format is that it allows the coverage obligations to be unbundled from the spectrum more effectively compared to the SMRA. ‘Unbundling’ provides advantages through the auction design for both of our objectives:
- a) Advantages for our coverage objectives:
 - i) It reduces the risk of unsold obligations, as bidders have the flexibility to package obligations with any of the spectrum offered in the auction.
 - b) Advantages for our efficient allocation objectives:
 - i) There is a low risk of unsold spectrum, as all spectrum can still be awarded, even if coverage obligations remain unsold due to low demand.
 - ii) All spectrum in the auction is unencumbered.
 - c) Advantages in balancing these two objectives:
 - i) Setting a maximum discount on the coverage obligations ensures that the obligations would be sold unless the opportunity costs in the auction exceed the maximum discount (because we would not award a coverage obligation where it decreases total auction value, including Ofcom’s reserve price bids for unsold lots).
- 7.134 In an SMRA, it would be challenging to have unbundled coverage obligations due to the aggregation risk associated with the format and the disadvantages of possible mitigations (such as minimum requirements and withdrawal rules). For the reasons set out above, if obligations were pre-attached, our current view is that we would attach each of the obligations to 2x10 MHz of the paired 700 MHz spectrum. This would apply for pre-attaching the obligations in both the CCA and SMRA. This would reduce the amount of unencumbered 700 MHz FDD spectrum to 2x10 MHz of 700 MHz, which may result in price and allocation distortions.
- 7.135 Another important advantage of the CCA format compared to the SMRA for this particular auction is the fact that the CCA is a more flexible format that is more robust to changes in circumstance.
- 7.136 For example, if we decided, in light of consultation responses, to amend the number or nature of the coverage obligations we would still be able to proceed with the award in a timely manner, as this would not require substantial changes to the auction regulations or the auction software. We consider that a CCA is therefore most likely to lead to a timely award of spectrum.
- 7.137 We recognise that there are some bidders which may experience challenges with the CCA format, particularly if they are a budget-constrained and/or a less experienced bidder. This primarily relates to the corporate governance challenges some bidders may face due to the

fact that the CCA is a second price auction, which means there is less certainty about the price they will pay.

- 7.138 However, we note that the CCA is a well-established format that has been used in auctions around the world. We consider that the challenges associated with the CCA format should be manageable for well-prepared bidders. We will also work with stakeholders and prospective bidders in advance of the auction in order to ensure that the auction format we adopt is well-understood.
- 7.139 We therefore propose to use a CCA for this auction due to its flexibility, and primarily its ability to allow for the ‘unbundling’ of the obligations from the spectrum. This is a material advantage, in that it would enable the auction to determine the appropriate balance between our policy objectives of ensuring efficient allocation of spectrum and improving mobile coverage.

Description of proposed CCA rules

- 7.140 Here we set out our proposed detailed rules for the CCA auction design. We appointed DotEcon and Auctionomics to advise on auction design for this award.

Lot structure

700 MHz spectrum

- 7.141 In the March 2018 consultation we set out our initial view that it would be appropriate to package the 700 MHz FDD spectrum, if it were absent any coverage obligations, into six lots of 2x5 MHz FDD; and the unpaired SDL spectrum into four lots of 5 MHz. We considered this appropriate on the basis that smaller lot sizes offered the maximum flexibility for operators to package the spectrum as they wished.
- 7.142 O2 agreed that packaging the 700 MHz FDD spectrum into six lots of 2x5 MHz was most appropriate. However, O2 suggested that 5 MHz of 700 MHz SDL spectrum was ‘almost certainly too small to support a viable business case’ and that SDL spectrum should be offered in 10 MHz lot sizes. Furthermore, it noted that 10 MHz would be the same size in MHz as a 2x5 MHz lot, which could allow for a common eligibility point weighting across all lots, and thus easier switching of demand between the two bands (given that they are potentially substitutable). We discuss the eligibility points associated with each lot category from paragraph 7.154, where we also address O2’s comment about eligibility between the 700 MHz lot categories.
- 7.143 O2’s concern was that, by introducing smaller lot sizes, we may be creating aggregation risks for some bidders. We agree that under certain auction formats, this may create large issues for bidders. However, we are proposing a CCA format that eliminates aggregation risks for bidders due to package bidding. A bidder that has a minimum use case of 10 MHz for SDL spectrum would face no risk of ever winning 5 MHz (provided it never bids for 5 MHz). Furthermore, this will still allow bidders with use cases of 5 or 15 MHz to bid for this amount.

7.144 We therefore propose to have six 2x5 MHz lots for the 700 MHz FDD spectrum, and four 5 MHz lots for the SDL spectrum.

3.6-3.8 GHz band

7.145 In the 2.3 GHz and 3.4 GHz auction earlier this year, we adopted 5 MHz lot sizes for the 3.4-3.6 GHz band. Even though the winning amounts of spectrum were in multiples of 10 MHz, there were a number of bids in multiples of 5 MHz. This suggests that bidders found it helpful to have 5 MHz lot sizes. Given that the 3.6-3.8 GHz band is similar in nature to the 3.4-3.6 GHz band, we propose to have twenty-four 5 MHz lots.

Coverage obligations

7.146 We propose to have one coverage lot category, with two lots in the category.

Figure 7.3: Proposed lot structure in the auction



Maximum discount for coverage obligations

7.147 We propose to set the maximum discount for the coverage lots within the range of £300m-400m, with a central case of £350m.

7.148 Annex 13 sets out the basis on which we propose to set the maximum discounts, and explains why we think that our approach is likely to incentivise bids for coverage and achieve an appropriate balance between costs and benefits.

Positive price constraint

7.149 As set out above in paragraph 7.96, there is a positive price constraint which means that bids and prices must be at least £1,000. We also outlined how this may give bidders the incentive to bid on additional spectrum, if they are not realising the full maximum discount when bidding on coverage due to the price of their spectrum package.

7.150 In the clock round, the price of any package will be the greater of the clock round price or £1,000. In the Supplementary Bids Round, only bids greater than or equal to £1,000 will be valid.

Incentives for straightforward bidding

7.151 We want to incentivise straightforward bidding as this promotes the optimal use of spectrum. In this regard, it is desirable if bidders are incentivised to bid:

- for their most profitable package in each clock round; and
 - for all their profitable packages in the Supplementary Bids Round.
- 7.152 Straightforward bidding for the most profitable package in each clock round assists the aim of the clock stage to promote price and package discovery, helping bidders to identify the likely prices of different spectrum packages and the packages that they have the best opportunity to win. Bids for all or a significant number of profitable packages in the Supplementary Bids Round assists in identifying the most efficient allocation of packages for the winner determination.
- 7.153 We outline below four elements of the auction design, which seek to promote straightforward bidding in the clock stage (or Primary Bid Rounds) and/or the Supplementary Bids Round. These are:
- a) Eligibility points
 - b) Relaxed Activity Rule
 - c) Relative Cap activity rule
 - d) Final Price Cap activity rule

Eligibility points

- 7.154 Eligibility points are used in the clock stage of a CCA to incentivise straightforward bidding. Each bidder has a number of eligibility points at the start of each round and can use these points to bid on lots. Each lot has a certain number of eligibility points associated with it, and bidders cannot bid on a package of lots greater than their current eligibility (except with relaxed bids, see 'Relaxed Activity Rule' below).
- 7.155 The number of eligibility points a bidder starts with in any round will be the number of eligibility points it used in the previous round (except when relaxed bids are placed).²⁰⁶ A bidder's eligibility points in the first clock round would be based on its additional deposit payment before the start of the principal stage.
- 7.156 Including eligibility points in the auction is intended to stop bidders from withholding their demand in the early stages of the auction, as they would lose their eligibility points and be unable to bid on a larger package of spectrum later in the auction. Furthermore, eligibility points are used to establish a rate of substitution between lots in different categories, which applies during the clock rounds of the CCA.
- 7.157 For instance, a 1:1 eligibility point ratio means that bidders are able to substitute one lot in the first category for one lot in the second category and vice versa. In the CCA, with the Relaxed Activity Rule we propose, the choice of the eligibility point ratio is less important because bidders would be allowed to bid on packages of lots for which they do not have

²⁰⁶ An example of this would be a bidder having 10 eligibility points at the start of round Y. In round Y, the bidder only uses 8 eligibility points (meaning they could have bid on more lots) and the bidder loses eligibility points in this round. In round Y+1, the bidder starts with the number of eligibility points used in the previous round, which is 8.

enough eligibility, under conditions aimed at incentivising straightforward bidding (this is explained below).

- 7.158 We propose to have the following eligibility points for spectrum lots:
- a) 4 points for a 2x5 MHz 700 MHz FDD lot;
 - b) 1 point for a 5 MHz 700 MHz SDL lot;
 - c) 1 point for a 5 MHz 3.6 GHz lot.
- 7.159 We propose the above eligibility as we believe that, on a per MHz basis, a 2:1 ratio between the paired 700 MHz and the 3.6 GHz facilitates switching between the two bands. An operator would be able to switch between 2x5 MHz of paired 700 MHz and 20 MHz of 3.6 GHz spectrum; and similarly between 2x10 MHz of paired 700 MHz and 40 MHz of 3.6 GHz spectrum.
- 7.160 We have also proposed a 2:1 eligibility point ratio, on a per MHz basis, between the paired and 700 MHz SDL spectrum. This is due to the high probability of the SDL spectrum being materially less valuable than the paired 700 MHz spectrum.
- 7.161 The lower eligibility on the SDL spectrum mitigates the risk that a bidder can retain eligibility in the auction by bidding on the SDL spectrum, even if the paired 700 MHz spectrum is preferred. This would enable a bidder to somewhat mask its preferences in the early stages, and then transfer eligibility to its most preferred lots or packages later on. As this strategy involves bidding on less preferred packages in some clock rounds, it is undesirable.
- 7.162 However, we also recognise (as suggested by O2) that having a 1:1 eligibility point ratio per MHz may facilitate switching between the two lot categories. We currently believe that this is a lesser concern, given the proposed Relaxed Activity Rules facilitate switching between lot categories.
- 7.163 We propose no eligibility points for the coverage obligation lots. This is due to the possibility that bidders may not find it most profitable to bid on coverage from the start of the auction. This can arise when the spectrum package a bidder is interested in has a lower price than the maximum discount. Having no eligibility on coverage allows a bidder to include a coverage lot to their spectrum package with less difficulty in later clock rounds, once spectrum prices have increased.
- 7.164 Even though there are no eligibility points on coverage lots, we still consider there to be good incentives for bidders to include coverage lots in their clock round bids when it is most profitable to do so. This is due to the restrictions placed by the Final Price Cap in the Supplementary Bids Round if bidders do not end the clock round bidding on their most profitable package. The Final Price Cap, and its effects, is discussed further below.

Relaxed Activity Rule

- 7.165 The CCA enables bidders to express their full range of preferences, within certain restrictions aimed at ensuring consistent bidding behaviour. In most CCAs (including the UK

4G auction), the bidding restriction in the clock rounds has been based on eligibility points. However, using only eligibility points can cause issues to bidders moving demand between different lot categories in the clock stage.²⁰⁷ This provides the incentive to bid on larger packages of spectrum than would be most profitable in certain clock rounds, in order to retain eligibility points.

- 7.166 We are proposing, in certain circumstances set out in the illustrative auction procedures (annex 16), a Relaxed Activity Rule to overcome the difficulties associated with moving demand from one band to another at the prevailing clock round prices. We are therefore proposing to adopt a hybrid eligibility point/revealed preference approach, which we propose to implement through the Relaxed Activity Rule.
- 7.167 The Relaxed Activity Rule would allow bidders to submit bids during the clock rounds for packages that exceed their eligibility in a particular round, provided that doing so is consistent with the relative preferences that a bidder has expressed up to that point in the auction. The submission of bids above the bidder's eligibility may in some instances require raising the bids on other packages to ensure consistency. These are called chain bids and are described in more detail in annex 16.
- 7.168 This activity rule was used in the Irish Multi-Band Spectrum Award; a similar variation was also used in the Canadian 700 MHz auction.^{208 209}
- 7.169 We believe these rules would allow for more informative clock rounds, particularly when coupled with the Final Price Cap (which is described below).

Relative Cap activity rule

- 7.170 We propose to include a Relative Cap activity rule, based on revealed preferences. This ensures that bidders maintain their preferences throughout the auction, contributing to incentives to bid on their most profitable package in the clock stage rounds.
- 7.171 The Relative Cap sets a constraint on the packages a bidder has not bid on, relative to the package that it bid on. This means that if a bidder does not bid on its most preferred package in a clock round, it may have placed certain constraints on its preferred package. This may stop the bidder placing bids on its most preferred package, either in future clock rounds and/or in the Supplementary Bids Round, reducing the likelihood of it winning its preferred package.
- 7.172 We propose that the Relative Cap constraints are only created in eligibility reducing round bids in the clock stage. We do not propose to have this apply to non-eligibility reducing

²⁰⁷ An example of this is if a bidder is interested in two packages, Y and Z. Package Y requires a higher amount of eligibility points. Based on the prices in a given round, the bidder may find it more profitable to bid on package Z, which would result in a reduction in eligibility points. In the later rounds, the price of package Z may rise relative to package Y, making package Y more profitable for the bidder. The bidder would like to place a bid on Package Y, however, the bidder would not have enough eligibility points to bid on package Y. It would therefore be unable to bid on their most preferred package. The bidder may pre-empt this problem by retaining a greater number of eligibility points in the earlier rounds, but this would require the bidder to bid on a less preferred package to retain flexibility in the auction. This is undesirable as the bidder is not bidding straightforwardly in each clock round.

²⁰⁸ More information available at <http://www.comreg.ie/fileupload/publications/ComReg1252.pdf>

²⁰⁹ More information available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf10598.html

rounds to allow bidders some flexibility to change their preferences in the auction. This allows bidders to update their bidding strategies to take account of considerations such as common value uncertainty or a binding budget constraint.

7.173 More information on the Relative Cap is available in annex 16.

Final Price Cap activity rule

7.174 We also propose adding a further constraint to the range of allowable bids in the Supplementary Bids Round. This is a variant of the Relative Cap, called a Final Price Cap. A Final Price Cap constrains the supplementary bids that bidders may place on all packages, except the one they bid for in the final clock round (the Final Clock Package).

7.175 The Final Price Cap limits the supplementary bid on any package 'Z' to the highest bid placed on the Final Clock Package plus the difference in value between package Z and the Final Clock Package at the final clock round prices.

7.176 In other words, if a bidder wishes to bid for lots in addition to its Final Clock Package, the maximum bid for each of those extra lots will be the clock price in the final clock round. Similarly, the maximum supplementary bid that a bidder may place on a package that is smaller than its Final Clock Package is the maximum bid placed on the Final Clock Package minus the difference in value between the two packages at the final clock round prices.

7.177 The Final Price Cap aims at providing a strong incentive for bidders to bid for their preferred package during the clock rounds. If a bidder does not bid on its preferred package in a clock round, and this turns out to be the final clock round, the bidder may be prevented from expressing its true relative preferences in the Supplementary Bids Round.

7.178 The bidder may therefore win its Final Clock Package, even though it would have preferred another package based on the final prices. Since the bidder does not know which round will be the final clock round, the bidder has stronger incentives under the Final Price Cap to bid on its most profitable or preferred package in every clock round.

7.179 A consequence of the Final Price Cap is that the final clock round is likely to be a better indication of the final outcome of the auction after the Supplementary Bids Round in terms of allocation of spectrum. In particular, if there are no provisionally unsold lots at the end of the clock rounds, and if no bidder has submitted a relaxed clock bid in the final clock round, the final outcome of the auction is likely to be the outcome of the clock rounds.²¹⁰

7.180 If there are provisionally unsold lots at the end of the clock rounds, bidders may be able to ensure that they win their Final Clock Package by placing a so-called 'knock-out bid'. A bidder who submits such a bid for its Final Clock Package and does not raise any bids for

²¹⁰ Bidders in this circumstance would have already bid at the final clock round prices for all the lots included in their Final Clock Packages. In most CCAs, no bidder would be able to bid for extra lots at a price which exceeds the final clock round prices, ensuring no bidder could be outbid and, therefore, the final clock round outcome could not be altered. Due to the positive price constraint, in this auction there may be some scope to change the final allocation. This is possible if some packages, when a coverage lot is added, would be negatively priced at the final clock prices and had not been bid on in the final clock round. In the Supplementary Bids Round, the activity rules would allow a bidder to place a bid above the final clock prices on packages that were negative in the final clock round.

other packages above its price in the final clock round is guaranteed to win its Final Clock Package.²¹¹

- 7.181 This Final Price Cap allows bidders to make a better assessment of both the packages they have the best opportunity to win and the maximum price they may need to pay. This may allow them to submit a set of bids that will ensure they obtain a desired result without having to reveal their full valuation for the packages on which they bid. It is also likely to reduce the difficulties that budget-constrained bidders face as they are better able to assess the packages they should focus on and whether the prices are likely to be within their budget.

Information policy

- 7.182 Before the auction begins, we propose to disclose the total number of qualified bidders and their identity. This is the same process we followed for previous auctions such as our recent award of the 2.3 GHz and 3.4 GHz bands.

Limited excess demand information for spectrum during clock rounds

- 7.183 During the auction, we propose to disclose a limited amount of information about aggregate demand at round prices for spectrum during clock rounds, balancing the aim of promoting price and package discovery with the risks of strategic bidding.
- 7.184 We recognise that some information on levels of aggregate demand in lot categories during the clock round is beneficial to bidders for efficiency reasons. In circumstances where there is common value uncertainty (i.e. the value of the spectrum is common but unknown to bidders), information about the level of aggregate demand in each lot category may allow individual bidders to improve their estimates about how much the spectrum is worth. Such information can also assist package discovery, assisting bidders to identify the packages that they have the best opportunity to win.
- 7.185 Furthermore, similar to the points noted above for the Final Price Cap, bidders that are budget constrained may be able to better manage their bids, both in terms of the packages to focus on and forecasting more accurately the final prices. We have provided the level of aggregate demand to bidders in the previous CCAs we ran, such as the UK 4G auction in 2013.
- 7.186 However, there are risks associated with revealing precise levels of aggregate demand, particularly the opportunities this may open up for strategic bidding. In the extreme, this can facilitate tacit collusion. More generally, it may increase the scope for bidders to bid strategically, which would ultimately reduce the information value of the clock rounds.
- 7.187 For instance, if bidders know the clock rounds are not likely to end soon, they may bid for a larger package than they would otherwise, based on their valuations, in an attempt to relax their Relative Cap. A more relaxed Relative Cap, in turn, allows bidders more room to place

²¹¹ This strategy may not be available to bidders who submit a relaxed primary bid in the final clock round. In this circumstance, bidders may only be able to ensure that they win one of a number of packages they have bid for during the clock rounds but not necessarily the Final Clock Package.

bids in the Supplementary Bids Round that could impact the prices paid by their competitors.

- 7.188 In addition, bidders might try to bring the clock rounds to an earlier end. This might be aimed at generating provisionally unsold lots in the final clock round and therefore cause greater uncertainty about the final outcome and prices.
- 7.189 At the extreme, full information on aggregate demand could give bidders opportunities to reduce their demand to pay lower prices through tacit collusion.
- 7.190 We believe a degree of uncertainty about whether the clock rounds are nearing an end should discourage such behaviour, especially with the Final Price Cap (which should provide incentives for bidders to bid in such a way as to end the clock rounds with their preferred package).
- 7.191 Striking the right balance between promoting price and package discovery and limiting the opportunities for strategic bidding involves regulatory judgement. We are currently minded to adopt an information policy where, after the end of each clock round, bidders are informed whether the level of excess demand for each spectrum lot category is less than or equal to the nearest higher multiple of 20 MHz (e.g. less than or equal to 20 MHz, less than or equal to 40 MHz, etc). If there was no excess demand for a spectrum lot category, we would simply inform bidders that demand is less than or equal to 20 MHz.
- 7.192 This is similar to the information policy we adopted in our recent award of the 2.3 GHz and 3.4 GHz bands (albeit that was an SMRA, not a CCA).

No aggregate demand information after the final clock round

- 7.193 We are not minded to reveal any information on aggregate demand after the final clock round.
- 7.194 We have considered the option of revealing full demand information after the end of the clock stage, recognising that this would have the benefit of helping bidders calculate their 'knock-out' bids. However, we note that bidders could use demand information following the final clock round to bid strategically in the Supplementary Bids Round to drive up the prices of other bidders. For example, if there are no unallocated lots in the final clock round, bidders could submit a number of risk-free bids, which may increase prices for other bidders. We think revealing no information for the final clock round would mitigate this risk, while the limited demand information we propose during other clock rounds would help to provide enough information to bidders going into the Supplementary Bids Round.
- 7.195 Revealing limited information in the clock rounds could lead to asymmetric information between bidders. Some bidders, particularly those bidding on large amounts of spectrum, could know more by putting together their own bids with the limited information policy. These bidders may be able to engage in more strategic behaviour, such as price driving. In addition, some bidders may have less knowledge of what bid they need to place in the Supplementary Bids Round in order to secure their Final Clock Package (i.e. calculating their 'knock-out' bid). This is due to some bidders having less information on how many

provisionally unsold lots there are in the final clock round. Asymmetric information in the auction is undesirable, however, we still consider revealing less information in the clock stage to be appropriate, given the risk of strategic bidding with more information (as set out in the above).

No aggregate demand information for coverage lots

- 7.196 We propose revealing no information on aggregate demand for coverage lots. This is because there is more scope for bidders to bid on coverage strategically due to our proposal to associate no eligibility points with coverage. An example of strategic bidding would be a signalling strategy, whereby bidders bid on coverage lots in one clock round, and then do not bid on coverage in another. We consider that this risk is mitigated by revealing no demand information on coverage.
- 7.197 In addition, unlike spectrum lots, there should be no common value uncertainty among bidders for coverage. This is because bidders' valuation for coverage should be based on their own assessment of the cost of (and revenue from) the coverage obligation.
- 7.198 There is therefore less of a need to reveal demand information for coverage lots, beyond the information that will be naturally provided by price movements, as bidders should not need this information to make informed bids.

Price driving

- 7.199 Submitting a price driving bid would require a bidder to place a bid above its intrinsic valuation for a spectrum package in order to raise the price paid by other bidders. In most instances, this is done at some risk to the price driving bidder since it may unintentionally win a package above its valuation of spectrum. The bidder would therefore have to take into account the possibility of winning an unwanted package when submitting a price driving bid, which we believe is a material disincentive to submitting such bids.
- 7.200 However, increasing the predictability of the provisional outcome at the end of the final clock round reduces uncertainty. When all lots are allocated in the final clock round, it is possible that this could allow bidders to submit low risk bids in the Supplementary Bids Round aimed at pushing up the prices paid by their competitors.
- 7.201 We believe the impact of such strategies is limited, as prices may only rise above the prices prevailing in the final clock round if there are provisionally unsold lots at the end of the clock rounds. Under the Relaxed Activity Rule we expect the flexibility in the clock rounds to be increased, reducing the likelihood of provisionally unsold lots.
- 7.202 In addition, price driving bids are constrained by the Relative Cap and Final Price Cap, which require consistency with the preferences revealed in the rounds when bidders reduced eligibility. Therefore, bidders may only be able to marginally raise bids for packages they wish to acquire without risk.
- 7.203 This is because in order to deviate materially from true valuations, a bidder would need to adjust its bidding strategy during the clock rounds. Failing to bid for the most profitable

package in the later rounds introduces a risk of ending up with a less preferred package in the final clock round.

- 7.204 We also believe that the possibility of submitting price driving bids is reduced by the limited information policy we are minded to adopt. Bidders would have less information about aggregate demand, making it more difficult to predict what packages their competitors are bidding on. This makes price driving bids more risky to submit, given the increased possibility that they have misjudged what their competitors are bidding on.

Packaging concern

- 7.205 In the winner determination of the CCA, there can be a packaging issue of whether the bids submitted in the auction essentially 'fit' together. For example, if there were ten lots on offer and two bidders who only ever submitted bids with six lots, the result of the auction would be that one of these bidders would win six lots and there would be four unsold lots. In this simple example, the unsold lots are due to bidders not making bids for other packages, such as a bid for a package of four lots.
- 7.206 With more bids for different packages, the risk of a combination of packages from different bidders failing to fit together is reduced. But in the example with only two bids, the number of lots available is finite, so the auctioneer cannot generate two additional lots in order to ensure there is no unsold spectrum.
- 7.207 In the unbundled CCA, there is the potential for a similar situation to arise either with the spectrum lots or the coverage lots. Bidders could reduce the risk through the number and range of bids they choose to make (and we seek to incentivise such bids). Beyond that, due to the available supply of spectrum lots, there are limits to what can be done to mitigate the risk for spectrum lots. However, the number of coverage lots is a constraint set by Ofcom. In theory, these could be increased, if necessary, to solve the packaging concern. We illustrate how this might work in the example below.
- 7.208 In this example there are six spectrum lots (6S) and two coverage lots (2C) and three bidders. The bidders have made the following clock round bids.
- Bidder X: Exited clock rounds with a bid on 2S + C at 130
 - Bidder Y: Bid on 2S + C at 150 in the final clock round
 - Bidder Z: Bid on 2S + C at 150 in the final clock round
- 7.209 Suppose the bidders do not submit any additional bids in the supplementary stage. There are three bidders who have all only submitted bids including a coverage lot, while there are only two coverage lots. There is no packaging issue on the spectrum as there are six lots available, and bidders have expressed demand for all six lots. The result is that Bidders Y and Z win, resulting in two unsold spectrum lots (as Bidder X cannot win only part of the package it bid for). This raises a total value of 300 in the auction.
- 7.210 If the number of coverage lots were increased to three, then a higher value in the auction can be achieved with 430. Each of the bidders would win two spectrum lots and a coverage

obligation. The only reason to increase the number of obligations would be to achieve to the higher value in the auction as a result of selling unsold spectrum lots.

- 7.211 This solution would therefore involve allowing more than two coverage obligations to be awarded in the winner determination if doing so would increase the total auction value. This would only be the case if there were unsold spectrum lots that, absent the restriction on the number of coverage lots, would otherwise be awarded. For the purpose of the Primary Bid Rounds, the supply of the coverage lots would be fixed to two, however, in the winner determination the number of coverage lots may be more than two.
- 7.212 However, we believe that bidders have incentives to include bids with and without the coverage obligation if these bids are profitable to place. In the example above, there was no excess demand on the spectrum lots so the price would not have risen on these lots in the clock round. With only two coverage lots, Bidder X could therefore have also submitted a winning bid on a package of two spectrum lots without a coverage obligation, assuming it had a value for 2S above the reserve price.
- 7.213 We think that including a solution to increase the number of coverage obligations if there is unsold spectrum would add complexity and potentially confusion into the auction, as the number of obligations would not be fixed.
- 7.214 Therefore, we do not consider it necessary to include any additional solution to address the packaging concern. However, we welcome stakeholders' views on whether they consider this a significant concern.

Assignment stage

- 7.215 Upon completion of the principal stage of the auction, which determines the amount of spectrum that each bidder wins in each lot category, we propose to hold an assignment stage to determine the exact location of the spectrum won by each bidder.
- 7.216 We are proposing a single-round, sealed-bid auction where bidders would be invited to bid for the exact location of their frequencies, amongst the permissible assignment plans (explained below). If there is only one permissible assignment plan, then bidders would be assigned the frequencies corresponding to the spectrum they won in the respective band in accordance with this assignment.
- 7.217 If, as is more likely, there are multiple assignments that meet these requirements, then bidders who would be assigned alternative frequencies in different assignments would be invited to submit bids for these alternative options. We would then identify the highest value combination of bids that can be accommodated. Assignment stage bids are considered separately for each of the three spectrum bands.
- 7.218 Bidders do not have to submit assignment bids to be assigned frequencies that correspond to the amount of spectrum they won in the principal stage. Therefore, participation in the bidding process of the assignment stage is optional.
- 7.219 For each of the three bands offered in the auction, we would only consider assignment plans in which each bidder is assigned a contiguous frequency block that corresponds to

the bandwidth they won in the principal stage. Any unsold spectrum would form a contiguous block. We believe this rule is likely to lead to the most efficient use of the spectrum.

- 7.220 In the event a bidding process for the assignment stage is needed, Ofcom would schedule a single round of bidding in which the relevant bidders will have the opportunity to submit bids for their preferred frequency assignments.
- 7.221 In such circumstances, we propose that assignment stage prices, which are additional to base prices from the principal stage, are calculated using a second price rule. We believe a pay-as-bid rule would create complexity for bidders. In a sealed-bid, pay-as-bid auction bidders have an incentive to bid below their valuations in order to extract some surplus, in the event that they are awarded a location that they bid for. To do this, bidders would need to form expectations as to how other bidders are likely to bid. If the expectations that bidders make are wrong, we may fail to assign the frequencies in accordance with bidders' valuations, which would result in an inefficient outcome.
- 7.222 We have used a single-round, sealed-bid auction with a second price rule for assignment stages in previous auctions, including the UK 4G auction in 2013 and the 2.3 GHz and 3.4 GHz award in 2018.
- 7.223 A final price for each bidder would be calculated after the assignment stage, which combines the base price, resulting from the principal stage of the auction, and any additional prices arising from the assignment stage.

Deposit

- 7.224 We propose that, along with their application, applicants would need to submit an initial monetary deposit which might be forfeited, in whole or in part, if the applicant subsequently breaches the award regulations. In addition, before the first round of the auction, qualified bidders would need to provide an additional deposit to Ofcom which would determine the bidder's initial eligibility level. Any interest made by Ofcom while holding the deposits would be returned to the Consolidated Fund.
- 7.225 We propose that the initial eligibility will correspond to the maximum number of spectrum lots that could be acquired by a bidder using their total deposit at the reserve prices without including coverage obligation lots. Ofcom will provide guidance on the deposit requirements for all possible initial eligibility levels.
- 7.226 We propose that, at any point during the auction, Ofcom may require bidders to increase their deposits up to an amount equal to the highest bid submitted so far by the bidder. Given that the CCA is a second price auction and bidders are likely to pay a lower amount than their bid, we may only ask bidders to increase their deposit to a fraction of their highest bid. We intend to publish more information on the deposit requirements closer to the start of the auction, most likely in the bidder guidance document.

Spectrum reserve prices

- 7.227 We generally adopt a conservative approach to setting reserve prices. We have considered two main conservative approaches. The first is to set a low reserve price, but sufficiently high to deter frivolous bidding. The second is to set higher prices that are closer to, but materially lower than, benchmarks for possible market value.
- 7.228 Low reserve prices, for example, may provide incentives for bidders to tacitly collude by increasing the pay-off from such behaviour in winning cheap spectrum. For a similar reason, they may also incentivise individual bidders to engage in strategic demand reduction (i.e. bid for a lower number of lots than they would otherwise, with the expectation that this would allow them to win less spectrum, but at a lower price).
- 7.229 These risks mean that we do not believe setting reserve prices purely to deter frivolous bidding would be appropriate in this case (with the possible exception of 700 MHz SDL spectrum).
- 7.230 However, high reserve prices will reduce the margin for price discovery during the principal stage of the auction. Price discovery allows bidders to improve their individual expectations about the likely value of the spectrum, and adapt their bidding strategy accordingly, which is desirable.
- 7.231 A high reserve price may also discourage participation, particularly from smaller bidders. There are many possible uses and users for the spectrum, and we believe the auction should not unduly preclude bidders from having an opportunity to compete in the auction. In addition, high reserve prices may cause a risk of unsold spectrum.
- 7.232 We propose to set reserve prices that are materially lower than our benchmarks for possible market value (where meaningful benchmarks are available).²¹² This would provide room for relevant price discovery, while still mitigating concerns about tacit collusion and strategic demand reduction.

Benchmarks for market value

700 MHz FDD spectrum

- 7.233 We have identified spectrum awards in European countries which included the 700 and 800 MHz bands. We have used prices from these awards to derive UK-equivalent absolute value benchmarks by band and relative values between these bands in the benchmark countries.
- 7.234 A number of country-specific factors have the potential to affect auction prices in comparator countries relative to the UK. For this reason, absolute auction prices may not provide reliable indicators of the value of spectrum in the UK. Some country-specific

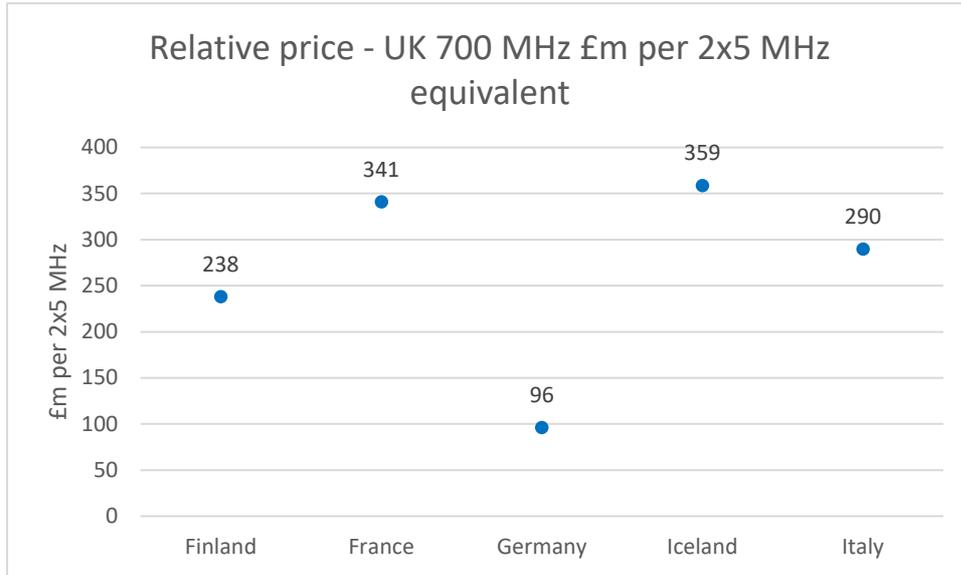
²¹² This is different from the approach Ofcom uses for setting Annual Licence Fees (where we also use evidence on benchmarks for market value). In setting Annual Licence Fees, Ofcom takes a conservative interpretation of the evidence to determine market value, whereas in this auction we wish to set reserve prices below market value to avoid unsold spectrum, encourage participation and allow a margin for price discovery.

factors, such as income levels and willingness to pay for mobile services, will be reflected in the PPP estimates which we have used to derive absolute benchmarks.

- 7.235 However, other differences in auction values are more difficult to address in a robust way – for example the good propagation characteristics of lower-frequency bands may be more or less important depending on the level of urbanisation and population density in a country. In general, we expect that relative values are less likely to be affected by country-specific factors than absolute values.
- 7.236 For 700 MHz FDD spectrum, we focus on the relative value of 700 MHz to 800 MHz licences in countries where both bands have been auctioned. We consider this is likely to be the most informative benchmark evidence for the value of 700 MHz spectrum in the UK. We use absolute benchmarks as a cross-check on our findings.
- 7.237 The derivation of international auction benchmark evidence points is consistent with our approach for calculating Annual Licence Fees for 900 MHz and 1800 MHz frequency bands.²¹³
- 7.238 At a high level, the steps we followed were:
- a) We looked at 700 and 800 MHz auction prices in five European countries (Finland, France, Germany, Iceland and Italy) where these spectrum bands have been auctioned.
 - We applied a series of adjustments to these price benchmarks to control for cross-country variations in licence duration, coverage obligations, payment method, and delay between the auction date and the licence start date.
 - We calculated the price ratio between the average value of 700 MHz spectrum and the average value of 800 MHz spectrum for each country.
 - We calculated the relative price of 700 MHz spectrum for the UK by taking the UK value of £33m per MHz of 800 MHz spectrum and multiplying this by the price ratios calculated in step c) for each country.²¹⁴
 - We adjusted these values to reflect October 2018 prices by applying CPI inflation since March 2013.
- 7.239 Following this methodology, we found the results below.

²¹³ Statement on the “Annual Licence Fees for 900 MHz and 1800 MHz frequency bands”, <https://www.ofcom.org.uk/consultations-and-statements/category-2/annual-licence-fees-900-1800-mhz>.

²¹⁴ Our rationale for using the £33m per MHz of 800 MHz spectrum is explained in the Statement on the “Annual Licence Fees for 900 MHz and 1800 MHz frequency bands”

Figure 7.4: 700 MHz FDD relative benchmarks in £m per 2x5 MHz based on October 2018 prices**Figure 7.5: 700 MHz FDD absolute and relative benchmarks in £m per 2x5 MHz based on October 2018 prices**

	Relative value (2x5 MHz)	Absolute value (2x5 MHz)
Finland	£238m	£108m
France ²¹⁵	£341m	£355m
Germany ²¹⁶	£96m	£145m
Iceland	£359m	£19m
Italy ²¹⁷	£290m	£475m

²¹⁵ The 2013 Ofcom Consultation on Annual Licence Fees noted that the 800 MHz auction in France has reduced evidential value for assessing appropriate market prices as it was a hybrid tender which included commitments to host MVNOs as well as a financial bid.

²¹⁶ The 2015 Ofcom Consultation on Annual Licence Fees highlighted that the price of 800 MHz spectrum in the German auction was likely to be an overstatement, while the price of 700 MHz may be understated, meaning that our relative value for 700 MHz spectrum is at risk of understatement. This is due to the lack of certainty around the future availability of 700 MHz during the 800 MHz auction, the fact that 700 MHz and 900 MHz were sold in the same auction thus potentially reducing the market value of low frequency spectrum and our view that strategic demand reduction may have taken place during the 700 MHz auction (see below).

²¹⁷ The 2015 Ofcom Consultation on Annual Licence Fees highlighted that 800 MHz spectrum prices may have been overstated in the Italian auction due to the lack of certainty around the future availability of 700 MHz spectrum during the auction.

- 7.240 In order to identify a suitable number to propose for 700 MHz band reserve prices, we have focused on the lower end benchmarks in order to set reserve prices that are materially lower than possible market values.
- 7.241 Germany has the lowest relative value of our benchmark countries at £96m for 2x5 MHz.²¹⁸ This is materially lower than most of the other benchmark prices, which are more closely clustered together between £238m and £359m. Finland's relative value of £238m for 2x5 MHz is at the lower end of this group. We also note that our reserve price for 800 MHz spectrum in the UK was £225m, which adjusted to October 2018 prices is £245m.
- 7.242 Taking account of these factors, we propose to set a reserve price for 2x5 MHz of 700 MHz spectrum within the range of £100m-£240m. We will update our analysis of benchmarks for reserve prices based on upcoming auctions for 700 MHz taking place between now and the publication our statement.²¹⁹

700 MHz SDL spectrum

- 7.243 We have not identified any benchmarks from auctions of 700 MHz SDL spectrum to assess market value or a suitable reserve price for this spectrum.²²⁰ In the absence of meaningful benchmarks for market value, we would adopt the first option of a low reserve price and propose £1m per 5 MHz lot. However, before our final statement we will see if meaningful benchmarks can be obtained from auctions taking place between now and the publication of that statement.²²¹

3.6-3.8 GHz spectrum

- 7.244 To assess a reserve price for spectrum in the 3.6-3.8 GHz band, we have looked at market prices in the UK's 3.4-3.6 GHz band as a benchmark. We consider this to be the most reliable benchmark, as the bands are very similar and using a UK benchmark instead of international benchmarks for this band allows us to accommodate UK-specific market characteristics, meaning that fewer adjustments are necessary.

²¹⁸ In our view, bidding in the 700 MHz band in the German 2015 auction may have been affected by strategic demand reduction and bid signalling with some similarities to the 900 MHz band in the same auction. We concluded there was a risk that the price of 900 MHz in the 2015 auction understated market value in Germany. See paragraphs A8.422-A8.431 and A8.446-A8.448 of the 2015 ALF for 900 MHz and 1800 MHz statement, https://www.ofcom.org.uk/data/assets/pdf_file/0032/78629/annex_8.pdf.

²¹⁹ We note that the 700 MHz auction in Sweden concluded in December 2018 and that Denmark and Switzerland are due to hold auctions of 700 MHz spectrum before or during H1 2019. We may therefore use these countries, as well as any others with relevant data points, as international benchmarks to update our reserve prices. We have undertaken a provisional assessment of the Swedish 700 MHz auction and our initial calculations suggest that the relative benchmark is higher than the other countries on our list.

²²⁰ In Italy's September 2018 auction there were no bids for 700 MHz SDL frequencies, which went unsold. The reserve price was set at €84,559,099 for 5 MHz of SDL spectrum. There are now plans to assign these following a different procedure. In Sweden's December 2018 auction there were also no bids for 700 MHz SDL frequencies, which went unsold with a reserve price of SEK 50,000,000 per 5 MHz.

²²¹ As above, we may consider the 700 MHz auctions in Denmark and Switzerland, as well as any other countries with relevant data points, as international benchmarks to inform our final reserve prices.

- 7.245 In our 2018 award of the 2.3 and 3.4 GHz bands, we set a reserve price of £1m for each 5 MHz lot of 3.4-3.6 GHz spectrum. This reserve price was the round price for the first principal stage round.
- 7.246 In the principal stage of the 2.3 and 3.4 GHz auction, spectrum in the 3.4-3.6 GHz band was won by three of the four mobile operators at the price of £37.8m per 5 MHz.²²²
- 7.247 We have considered whether the following factors, which may not have been relevant to bids for spectrum in the 3.4-3.6 GHz band, may influence the market value of spectrum in the 3.6-3.8 GHz band:
- a) **Existing 5G spectrum holdings** – We have considered whether operators’ existing holdings in the 3.4-3.6 GHz band might influence their valuation of spectrum in the 3.6-3.8 GHz band. Although all four operators already hold usable 5G spectrum in the 3.4-3.6 GHz band, we consider that it was sufficiently clear that we intended to auction 5G spectrum in the 3.6 GHz band, and that this would be factored into operators’ valuations of spectrum in both bands.
 - b) **Usability of the band** – We have considered whether the usability of the 3.6-3.8 GHz band is different from the 3.4-3.6 GHz band. A more detailed discussion can be found in annex 8. We expect that devices supporting the 3.4-3.6 GHz band will also support the 3.6-3.8 GHz band. Spectrum in the 3.6-3.8 GHz band will be usable in some parts of the UK before mid-2020, subject to coordination requirements to account for existing users. Most of the users will have left the band by mid-2020, thereby making the band useable nationwide by this date with only some minor deployment restrictions as a consequence of the coordination requirements. On balance, we consider that the 3.6-3.8 GHz spectrum may be useable slightly later than the 3.4-3.6 GHz band.
- 7.248 Considering this benchmark and our proposal to set reserve prices that are closer to but materially lower than possible market value, we propose to set a reserve price of between £15m and £25m per 5 MHz of spectrum in the 3.6-3.8 GHz band. We find it appropriate to set a higher reserve price for this band than we did for the 3.4 GHz band, when market values were less clear, as market evidence from the previous auction is now available.

Questions for consultation

Question 5: Do you agree with our proposal to use a CCA design for this award?

Question 6: Do you have any comments on the proposed detailed rules for our CCA design?

²²² O2 won 40 MHz of spectrum in the 3.4 GHz band at a higher cost of £39.7m per 5 MHz.

8. Coexistence issues for the 700 MHz band

- 8.1 There is a risk that a small number of digital terrestrial television (DTT) viewers may experience interference from new mobile services operating in the 700 MHz band.²²³ This section of the consultation sets out our proposals for ensuring that the holders of licences granted in this award will assist consumers affected by interference.
- 8.2 Our objective is to ensure that 700 MHz mobile services do not cause undue interference to DTT viewers - and, if they do, that new mobile licensees resolve any issues.

Nature and scale of interference risk from mobile to DTT services

- 8.3 New mobile services in the 700 MHz band will be using frequencies that were previously used for DTT transmissions. DTT will continue to operate in frequencies adjacent to the award bands.
- 8.4 In May 2017 we consulted on the potential interference risks between new mobile services and DTT.²²⁴ At the same time we published a technical assessment of those risks.²²⁵
- 8.5 Where possible, our technical analysis placed a priority on practical data over theoretical modelling. It suggested that TV installations may be sensitive to activity in adjacent frequencies and that there was a potential risk of interference to DTT services. The analysis indicated that most households will not be subject to any substantial interference following the launch of 700 MHz mobile services. However, a small number may be at risk of experiencing TV reception problems or losing reception.
- 8.6 In December 2017, we set out the conclusions arising from our consultation.²²⁶ These reinforced our assessment that the vast majority of households would not experience interference from 700 MHz mobile services. We concluded that:
- the impact of interference from mobile base stations into DTT will not exceed 36,000 households, accounting for less than 0.2% of DTT households in the UK;
 - there will be minimal risk of interference from mobile handsets.; and
 - receiver filters, which work by allowing wanted signals (DTT) to pass through while reducing unwanted interfering signals, will be the most technically effective means to mitigate interference from handsets and base stations. Receiver filters are small

²²³ In this section “interference” should be understood to mean harmful interference. There are many cases of interference that have no impact on TV viewing.

²²⁴ *Coexistence of new services in the 700 MHz band with digital terrestrial television*, May 2017, https://www.ofcom.org.uk/data/assets/pdf_file/0018/101619/Coexistence-of-new-services-in-the-700-MHz-band-with-digital-terrestrial-television.pdf

²²⁵ *Coexistence of new services in the 700 MHz band with digital terrestrial television*, May 2017.

²²⁶ *700 MHz Coexistence: Study of mobile uplink interference effects upon DTT reception*, May 2017, https://www.ofcom.org.uk/data/assets/pdf_file/0018/101655/700-MHz-Coexistence-Study-of-mobile-uplink-interference-effects-upon-DTT-reception.pdf

devices that can typically be plugged into the back of a TV set to resolve interference issues. This assessment of scale has informed our policy approach.

Similarities with the case of 800 MHz coexistence

- 8.7 The coexistence scenario for mobile and DTT coexistence in the 700 MHz band is similar to the one experienced following the introduction of mobile services into the 800 MHz band, auctioned for mobile use in 2013.²²⁷ The 800 MHz spectrum was also spectrum vacated by DTT and is exposed to similar interference mechanisms.
- 8.8 Ahead of the entry of mobile services into the 800 MHz band, Ofcom originally estimated that DTT services for up to approximately one million households might be affected by interference. To mitigate this risk, Ofcom:
- included conditions in new mobile licences requiring MNOs to work together to set up and fund a single consumer body to communicate with consumers in advance of roll-out and provide filters and installation support;
 - included a set of prescriptive key performance indicators (KPIs) in licences;
 - required MNOs to set aside £180m to fund the consumer body and an Oversight Board to provide advice to Ofcom on compliance with and the performance of the consumer assistance scheme. The payment amount per MNO was proportional to spectrum holdings.
- 8.9 In 2013, all four UK MNOs won spectrum in the 800 MHz auction. In line with their licence conditions they established Digital Mobile Spectrum Limited (DMSL, or brand name at800) as a single body to support DTT viewers affected by interference from new 4G services.
- 8.10 The ‘at800’ body has two main functions.
- **Communication** – at800 informs at risk viewers that they might suffer interference caused by the entry of 4G mobile services into the 800 MHz band. It sends postcards to viewers who live in the vicinity of 800 MHz 4G masts which are about to be activated and are considered at high risk of interference. It also manages an advice line for taking calls from people who believe they might be suffering interference.
 - **Mitigation** – at800 resolves viewers’ interference problems by providing 800 MHz filters or installation support. The primary means of mitigation is provision of a filter which most viewers can easily fit to the back of their television by themselves.²²⁸ As of January 2018, at800 sends a filter as a first option when a viewer contacts the advice line about interference. If viewers feel uncertain about fitting the filter themselves, or if they have external aerial amplification, then at800 will offer a visit by an engineer.

²²⁷ *Coexistence of new services in the 700 MHz band with digital terrestrial television (Update)*, December 2017, https://www.ofcom.org.uk/data/assets/pdf_file/0025/108655/update-coexistence-700-mhz.pdf

²²⁸ In research for 800 MHz coexistence, 95% of people said that fitting the filter having seen instructions was “easy”. *Freeview Interference: A quantitative research report*, October 2011,

An engineer visit is also available for viewers whose interference issue is not resolved following filter installation.

- 8.11 In practice, far fewer households have been affected by interference resulting from mobile in the 800 MHz band than originally forecast. DMSL has therefore downscaled its operations to reflect the actual size of the issue.
- 8.12 The 800 MHz experience has provided us with valuable operational insights which we can apply in our work on 700 MHz coexistence. We have also held discussions with the Oversight Board, which have helped us develop an initial view of some of the learnings from the 800 MHz experience.²²⁹ We outline the key lessons below.

It is very challenging to target accurately communications and assistance to affected consumers, and this drives costs

- 8.13 A significant number of households currently suffer issues with their Freeview reception for reasons unrelated to 4G roll-out. Research indicates that around 30% of viewers experience television-unrelated reception issues²³⁰, much greater than the less than 0.2% of viewers confirmed as experiencing 800 MHz interference.²³¹
- 8.14 The communications activity carried out by at800 has meant that some of these households may have benefitted from the assistance intended for those affected by 4G roll-out. As of the end of August 2018, just over a third of the household visits made by at800 aerial installers were confirmed as being related to 4G mobile interference.²³²
- 8.15 As the likelihood of viewers suffering interference is in large part related to the quality of their TV installations, it is very difficult to predict in advance which households will be affected. At800 has used modelling to identify households at risk of interference and has targeted communications at these households. However, due to the wide variations in the susceptibility of households to interference, the number of postcards sent (more than 20 million) far exceeds the 25,000 confirmed 4G interference cases to August 2018.

The framework, including KPIs, should allow for operational flexibility

- 8.16 At800 has consistently delivered a high standard of service to viewers affected by interference problems. Ofcom agreed changes to the original KPIs and Operational Conditions, as proposed by at800 and the Oversight Board, partly as a result of the reduced

²²⁹ Information on the Oversight Board and its membership is available at <https://www.gov.uk/government/groups/4gtv-co-existence-oversight-board>

²³⁰ See *Viewers' experience of television reception*, 5 April, 2016, https://www.ofcom.org.uk/data/assets/pdf_file/0023/73922/viewers-experience-of-tv-reception.pdf, p.4

²³¹ See *Coexistence of new services in the 700 MHz band with digital terrestrial television : Consultation document*, 9 May 2017, https://www.ofcom.org.uk/data/assets/pdf_file/0018/101619/Coexistence-of-new-services-in-the-700-MHz-band-with-digital-terrestrial-television.pdf, p.1

²³² Based on Oversight board paper(s). It's reached by dividing the number of confirmed 4G cases by the number of engineer visits to unique addresses. See for example https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/659420/Oversight_Board_Report_27_Sept_2017_FINAL.pdf

risk of interference from 4G to DTT, as well as in recognition of a need to provide at800 with greater flexibility to adjust its operation as understanding of the issues evolved.

- 8.17 This resulted in a streamlined KPI and Operational Conditions regime, involving a single overarching KPI relating to timely service restoration, supported by sub-KPIs.
- 8.18 The difference between the number of forecast and actual interference cases, and the evolution of at800's operation, suggests that any framework for a new scheme for 700 MHz coexistence needs to allow for operational flexibility. The providers of viewer support may be best-placed to design how any support scheme or schemes should operate. This includes the creation of effective KPIs. A less prescriptive approach could be appropriate for 700MHz coexistence, so long as it ensures that key outcomes are achieved.

Our approach to developing and assessing policy options

- 8.19 Given the potential for consumer harm resulting from interference (and notwithstanding the limited number of forecast cases), our provisional view is that regulatory intervention is appropriate to manage the risk in line with our duty to secure optimal use of the spectrum. This will protect viewers of DTT services - and the benefits those services provide - whilst facilitating the reallocation of the relevant spectrum to valuable mobile services.
- 8.20 To assess the options for the form that intervention should take, we have developed the following four criteria that support our policy objective of ensuring that 700 MHz mobile services do not cause undue interference to DTT viewers (and that, if they do, the mobile licensees resolve it).

A: Will the option avoid undue consumer harm?

- 8.21 Our analysis suggests that a relatively small number of undue interference cases will occur. However, a risk remains that without any support some consumers, particularly vulnerable ones, may struggle to resolve reception issues themselves. Alternatively, consumers may take a long time to resolve these issues or spend money in doing so. During this time, they will be without TV services.
- 8.22 One of our criteria for assessing policy options is therefore whether the option effectively mitigates the risk that consumers will experience harm.

B: Will the option be proportionate?

- 8.23 In line with our duties, one of our criteria for assessing policy options is to ensure that measures are cost-effective and proportionate to the scale of the harm that may be posed to consumers.

C: Is the option scalable?

- 8.24 We have said that the upper estimate for the likely number of 700 MHz interference cases is in the range of 25,000 - 36,000 consumers. However, the number of consumers who are

affected could be lower than this. Alternatively, there is a small risk that a greater number of consumers could be affected by interference.

- 8.25 Any solution for 700 MHz coexistence should be in proportion to the number of DTT viewers that we have forecast will be impacted by coexistence issues. However, these measures should be scalable in the event that the issue proves smaller or larger than forecast. Therefore, one of our criteria for assessing policy options is whether the policy option permits scaling to fit the actual size of the problem.

D: How does the option impact the benefits of introducing mobile into the 700 MHz band?

- 8.26 Opening the 700 MHz band up to use by mobile services should help meet the increasing demand for mobile data from consumers. The characteristics of the 700 MHz band make it suitable for improving mobile coverage.
- 8.27 Any solution we adopt for 700 MHz coexistence should not adversely affect roll-out of mobile services in the band. The option should give clarity to eventual 700 MHz licensees, allowing them to accurately estimate the value of the spectrum and mitigating the risk of delays to network roll-out, which could delay the delivery of the consumer benefits of mobile in the 700 MHz band.
- 8.28 As noted, we understand from discussion with stakeholders that many of the interference cases that at800 has addressed have not been related to the presence of mobile in the 800 MHz band. Consumers have benefitted from at800's work in these instances. However, this was incidental and not a policy goal. Therefore, any policy option should minimise the risk of licensees being required to resolve DTT interference cases unrelated to mobile in the 700 MHz band.

Who should viewer support assist?

DTT-only viewers

- 8.29 Many DTT viewers do not have other means of receiving TV. The options for intervention we have considered include an obligation for licensees to provide assistance to these viewers, for example by providing filters, installer support, and advice.

Viewers with Pay TV

- 8.30 Some DTT viewers who experience interference may also receive TV via a cable or satellite Pay TV subscription (e.g. from Sky or Virgin Media). While these viewers will be affected by interference, they will still be able to continue to watch TV programmes through their Pay TV provider. Any harm these viewers experience will consequently be smaller than DTT-only viewers, who will experience interference on their sole means of watching TV.

- 8.31 We propose that licensees should consider ways of providing help to these viewers that are proportionate to the more limited impact on them – such as by ensuring that filters are available via retail outlets close to them should they require it, and that advice is available.

Viewers with indoor aerials

- 8.32 The DTT network is planned for reception using rooftop aerials, not indoor aerials, and this is reflected in our spectrum management decisions in general.
- 8.33 In some areas, it may be possible to receive a signal using an indoor aerial, with varying reliability, but this is not in general our policy objective. Use of an indoor aerial makes an installation vulnerable to many causes of reception loss, and it may not be feasible to pinpoint what causes a specific case of loss of reception. We propose that advice, but not mitigation, should be made available to viewers using indoor aerials.

TV channels operated by Arqiva

- 8.34 It is possible that Arqiva will still be transmitting some DTT channels using a particular part of the 700 MHz band - the centre gap (733–758 MHz) – when the roll-out of mobile services in other parts of the 700 MHz band begins. Transmission of these channels has been permitted by the issue of interim multiplex licences.
- 8.35 Our October 2016 statement said we were minded to allow the interim DTT multiplexes to have continuing access using the centre gap frequencies until the mobile services are actually switched on. This remains our position.
- 8.36 However, we also decided that the responsibility to manage the impact of any incoming interference received by viewers watching services transmitted from the centre gap would sit with Arqiva. We will therefore not require any viewer support scheme run by the mobile operators to provide assistance to viewers who lose services carried by the interim multiplexes.

Vulnerable viewers

- 8.37 The viewers who experience interference may include vulnerable people. We propose that viewer support should make specific provisions in respect of these viewers, who may be at increased risk of harm on account of their vulnerability and may consequently require a higher level of support.

Policy options and assessment

- 8.38 We have identified three options that appear to be workable under the proposed criteria identified above. We set out these options below, together with our assessment.

1) Require 700 MHz licensees to provide support, with broadcasters delivering the ‘front line’ of that support

Description

8.39 Many households suffer issues with their DTT reception for reasons unrelated to mobile, such as poor aerial installation or problems with the receiving system. At800 has effectively found itself responsible for resolving such problems, whereas its responsibility should only cover interference cases caused by mobile services in the 800 MHz band. It might be preferable to split responsibilities so that this situation is not repeated in the case of 700 MHz. This option could work in one of two ways:

- Broadcasters (or Freeview) would use existing helplines to triage cases of interference and alert licensees to interference caused by mobile services in the 700 MHz band. Broadcasters would have the incentive to pass such cases to licensees, who would be required to rectify interference issues caused by mobile services through the provision of filters. In this first variation, licensees would not be required to provide proactive communications or installation support.
- Alternatively, this option could go further by introducing additional requirements on the 700 MHz licensees. Again, broadcasters would be responsible for running a helpline but, additionally, 700 MHz mobile licensees would be subject to an obligation to assist consumers who experience interference by providing filters. They would also be required to provide some proactive communications, such as local advertising. The licensees would also be required to provide more extensive installation support, including engineer visits for vulnerable people.

Assessment

8.40 This option would provide better protection for consumers than no regulatory requirement to support viewers:

- In the first version some potential for consumer harm remains due to the lack of proactive communications alerting users to interference in their area and a lack of information about who to contact. Without such communications, consumers affected by interference may be unsure of where to turn. Furthermore, as above, vulnerable consumers may be disproportionately affected if no assistance is offered.
- The second version would reduce the risk of consumer harm further. Though limited communications might miss out some people, it is likely that general community awareness of the problem would increase, and consumers would have more information about who to contact if they experience interference issues. It would also reduce the risk of harm to those who are most in need of installation assistance.

8.41 Our initial view is that either version of this option would be proportionate to the predicted scale of the issue, as there would be a clear opportunity to avoid unnecessary costs and waste, while still providing some consumer protection.

- 8.42 As outlined above, it is very difficult to target communications and assistance to affected consumers, and therefore it is hard to identify which households should receive postcards. Consequently, we would not prescribe postcards as the only acceptable method of proactive communications. A single helpline for all TV reception issues would also be more proportionate and cost-effective than a specific helpline for interference only, avoiding duplication of work and confusion among consumers around who to contact in the case of interference.
- 8.43 The flexible nature of this requirement to assist affected viewers means there would not be many barriers to stop licensees from increasing or decreasing their level of expenditure in response to their experience on the ground. The integration with the existing Freeview helpline would also help reduce fixed costs. Therefore, this option would be scalable.
- 8.44 There would likely be no significant direct impact on mobile consumers. Any mitigation scheme imposes some costs on the mobile operators, and this might indirectly affect mobile consumers.

2) Require 700 MHz Licensees to provide viewer support with detailed requirements set by Ofcom

Description

- 8.45 This option would require the 700 MHz licensees to provide a support scheme involving proactive communications and free filter installation in affected homes. The scale of these requirements and a detailed approach to fulfilling them would be determined by Ofcom and set out in obligations in the 700 MHz licences. The performance of the scheme would be measured against specific and prescriptive KPIs also set by Ofcom.
- 8.46 This option would be comparable to the viewer support scheme that has operated since 2017 to help viewers who lose DTT reception as a result of 700 MHz clearance events. It would also, in some respects, resemble the scheme designed for 800 MHz coexistence (at800).

Assessment

- 8.47 This option would offer a high level of consumer support and is likely to minimise consumer harm. It is likely that this option would achieve high consumer satisfaction rates, as has been the case with the support scheme provided by at800.
- 8.48 Our analysis suggests that interference cases resulting from reallocation of the 700 MHz band will not exceed 36,000, the maximum number of cases projected to be caused by the earlier 800 MHz network roll-out. We would aim to prescribe a scheme that is proportionate to the scale of the issue. However, a risk would remain that our assessment of the scale of the problem might be incorrect and, as a result, that a prescriptive scheme may prove costly and disproportionate.

- 8.49 If the scale of the problem proved smaller or larger than predicted, then under this option licensees may not find it straightforward to adjust the scheme to match the size of the issue.
- 8.50 This more prescriptive approach may provide certainty to bidders, reducing risks to auction efficiency. Prescriptive obligations may make it easier for the licensees to account for costs when preparing their bids. Prescriptive obligations could also make cooperation between licensees more straightforward.
- 8.51 On the other hand, in light of the experience of 800 MHz coexistence, the 700 MHz licensees may be better placed to estimate the actual costs of the scheme and to assess which specific interventions will be most effective.
- 8.52 There is therefore a risk that a tightly prescribed scheme will not be as efficient as it could be, or that we would need to make it more flexible at a later date to account for real life lessons (as it happened with 800 MHz). This may ultimately make the scheme more expensive than it needs to be, which could indirectly impact mobile consumers.

3) Our preferred option - a less prescriptive approach

Description

- 8.53 This option involves a flexible approach in which 700 MHz licensees would be required to provide consumer support.
- 8.54 Under this option, Ofcom would impose on licensees a high-level obligation to set up and operate a scheme to provide advice and assistance to viewers suffering undue interference from mobile services and to ensure they resolve it. The condition would not prescribe in detail how the licensees should set up and run a scheme (or schemes, since Ofcom would not mandate that licensees cooperate to deliver a single support scheme).
- 8.55 We would, however, as a pre-condition of their use of the spectrum, require licensees to submit to us for approval a joint plan setting out the approach they would take. A joint plan would be required to ensure that consumers have a good experience (as opposed to having to navigate several uncoordinated schemes).
- 8.56 We would provide an indication of what we might normally expect to see in this joint plan via guidance (see the draft proposed guidance in annex 19). The viewer support provided by licensees would need to achieve the objective of ensuring that 700 MHz mobile services do not cause undue interference to DTT viewers (and that, if they do, the mobile licensees resolve it). We propose that any plan would need to make provisions in at least four key areas:
- **Engaging with consumers** – Licensees will need to make appropriate provision for informing consumers who are at risk of being affected by interference. We would likely expect licensees to provide an advice line and to advertise that help is available.

- **Assisting consumers who experience problems** – Licensees will need to assist consumers who experience interference resulting from mobile in the 700 MHz band. The main form of remediation would likely be through filters.
- **Helping vulnerable consumers** – Licensees will need to take account of the needs of vulnerable consumers.²³³
- **Operational functions** – Licensees will have to take account of the operational side of supporting DTT viewers. This would likely include how the costs of viewer support would be funded and how performance would be tracked.

8.57 Ofcom would also retain the power to impose a fall-back plan should licensees submit no satisfactory joint plan (and we would have the power to take enforcement action, including imposing financial penalties assessed in light of Ofcom’s penalty guidelines²³⁴, against licensees who did not comply with their licence conditions).

Assessment

- 8.58 This option would provide a high-level obligation for 700 MHz licensees with the aim of avoiding undue harm to consumers (and the incentive to meet it, and to protect viewers, derived from the possibility of Ofcom enforcement action).
- 8.59 700 MHz licensees would be required to provide some level of communication and support to consumers but would be responsible for discerning the most effective measures, drawing on the benefits of practical experience.
- 8.60 Under this option, the licensees would be responsible for ensuring that the adopted solution is proportionate. They would have a responsibility to avoid undue harm to consumers as part of their licences. They would need to ensure there is enough funding to provide adequate support, with the freedom to spend more if they wish to.
- 8.61 This model would be scalable. Licensees would have the freedom to drop down to a simpler model or scale up to more comprehensive measures as the scale of the problem manifests itself.
- 8.62 That said, licensees would have an obligation to address interference problems caused by mobile in 700 MHz, so would be required to provide support to consumers even in the event that the scale of the problem proves larger than forecast. Ofcom would be able to enforce against this obligation should it prove necessary.
- 8.63 There is some risk that a less prescriptive approach could lead to uncertainty among licensees, who will need to work together to agree a solution. This could lead to uncertainty among licensees, who may not want to depend on their competitors’

²³³ We set out which consumers can be considered vulnerable in our draft guidance.

²³⁴ The current version of these guidelines is available at

https://www.ofcom.org.uk/_data/assets/pdf_file/0022/106267/Penalty-Guidelines-September-2017.pdf

cooperation in order to fulfil the requirements of their licence. We intend to mitigate this risk by:

- issuing guidance as described above; and
- retaining a power to impose requirements if licensees do not agree a satisfactory joint plan.

Summary of options

8.64 We have assessed our options under four criteria. A high-level summary of the options and our initial assessment is set out in the table below.

Figure 8.2: Summary of our initial assessment of policy options for 700 MHz coexistence

	Avoiding undue consumer harm	Proportionality and cost	Scalability	Effect on mobile consumers
1a/1b) Shared support	Lack of proactive comms could result in some consumer harm	Proportionate if there are a low number of cases and avoids waste and duplication	Scalable	No direct impact
2) Detailed requirements on licensees	High level of consumer protection	Risk that without flexibility, scheme will prove costly and disproportionate	Risk that it does not scale easily to low number of cases	Prescriptive conditions may reduce uncertainty, but risk higher costs
3) Less prescriptive approach	Obligation aimed at reducing consumer harm, particularly among vulnerable groups	Licensees will determine proportionate approach	Fully scalable	Risk of uncertainty could be mitigated by fallback condition and guidance

8.65 Our provisional view is that the less prescriptive approach best meets our criteria and would be the best option for achieving our policy objective.

Implementation of our preferred approach

8.66 We propose to include the following condition in the licences for 700 MHz spectrum:

“During the period this Licence remains in force, unless consent has otherwise been given in writing by Ofcom, the Licensee shall operate the Scheme²³⁵ and comply with its obligations in the Scheme Notice.²³⁶ The Licensee shall provide to Ofcom and any entity established as part of the Scheme, in such manner and at such times as they may reasonably require, such documents or other information as they may require for the purposes of the Scheme’s operation, monitoring that operation and assessing its appropriateness and effectiveness.”

8.67 As noted, our related draft guidance, for stakeholders’ consideration and comment, is in annex 19 of this document.

Assessment of plan based on whether it protects consumers

8.68 We propose that the licensees would have a 10-week window following the award of licences for the 700 MHz band to submit their joint plan to Ofcom for consideration. We propose to evaluate the plan in accordance with the objective and guidance we propose, and to respond to the licensees, within six weeks with our approval or otherwise.

Fall-back option in the event of no acceptable plan being proposed by the licensees

8.69 It is possible that discussions among the 700 MHz licensees to produce a joint plan could result in a deadlock. We consider this unlikely, given the incentives for them to work together and the experience the existing MNOs (who may acquire spectrum in the 700 MHz band) have in running the 800 MHz scheme.

8.70 However, as a precaution, we propose to retain fall-back powers to allow us to impose our own plan if no acceptable version is proposed by the licensees. In this case, we would require licensees to provide a viewer support scheme where we set detailed requirements. The costs for the scheme would be borne by the licensees, with costs shared out in proportion to the licensees’ holdings in the 700 MHz band.

8.71 The fall-back option would likely include the components given in our guidance in order to secure our policy objective in relation to protecting DTT viewers.

²³⁵ “Scheme” would be defined in the licence as “a scheme for the purpose of providing information and advice to DTT Viewers and assisting DTT Viewers to resolve undue interference suffered by them as a result of the Licensee’s use of the Radio Equipment, which meets the requirements in the Scheme Notice.”

²³⁶ The expression “Scheme Notice” would also be defined in the licence setting out the details of the way the Scheme would operate. It would reflect the Scheme as approved by Ofcom in response to the licensees’ joint plan or imposed by us.

Consultation questions

Question 7: Do you agree with proposed approach to coexistence in the 700 MHz band?

Question 8: Do you have any comment on the proposed licence obligation and guidance note (annex 19)?

9. Coexistence issues for the 3.6-3.8 GHz band

9.1 In this section we turn to potential coexistence issues relating to new mobile use of the 3.6-3.8 GHz award spectrum. We discuss the options available for managing these issues and then set out our proposals.

Background

9.2 New users of the award spectrum in the 3.6-3.8 GHz band will need to coexist with other in-band spectrum users as well as users in adjacent bands.

9.3 As set out in section 2, frequencies in the 3.6-3.8 GHz band are currently used for fixed links, fixed satellite services (to receive space-to-Earth transmissions) and wireless broadband (provided by UK Broadband).

9.4 In our February 2018 update²³⁷, we confirmed that we had:

- issued notices to revoke all fixed links licences in the band, with an effective date of 23 December 2022;
- varied 12 Permanent Earth Station licences and three grants of RSA, with an effective date of 1 June 2020; and
- varied one grant of RSA with an effective date of 1 September 2020.

9.5 We also said that we would work with fixed links licensees with the aim of migrating fixed links operations to alternative frequencies or technologies by June 2020 where possible.

9.6 In the remainder of this section we discuss:

- Interim protections for registered 3.6-3.8 GHz band users;
- In-band restriction zones around satellite earth stations; and
- Coexistence with users in the 3.8-4.2 GHz band.

Interim protections for registered 3.6-3.8 GHz band users

9.7 There will be a period of time between the award of the spectrum in 2020 and the variation or revocation of existing satellite and fixed links authorisations in the band during which we will need to maintain protections for these users.

9.8 In our October 2017 statement²³⁸ we said that we would continue to maintain appropriate protections for registered band users whose licence(s), or grant(s) of RSA, are revoked or varied (as applicable) until the relevant notice period had lapsed. Figure 9.1 below shows

²³⁷ https://www.ofcom.org.uk/_data/assets/pdf_file/0018/110718/3.6GHz-3.8GHz-update-timing-spectrum-availability.pdf

²³⁸ <https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz>

the satellite earth stations and fixed links for which the relevant notice period will lapse between June 2020 and December 2022.

Figure 9.1: Locations of satellite earth stations and fixed links with notice periods lapsing between June 2020 and December 2022



- 9.9 We have a process in place to coordinate new UK Broadband base station deployments with other registered users in the 3.6-3.8 GHz band. We propose to adopt a similar process to manage new base station deployments made by new licensees.
- 9.10 This means that, during the interim period prior to the notice period, new licensees in the 3.6-3.8 GHz band will need to submit to Ofcom technical information about each new base station they intend to deploy. Ofcom will use that information to assess whether the new base station is likely to undermine benchmark spectrum quality for existing registered satellite earth stations and fixed links.
- 9.11 New licensees will not be permitted to transmit from new base stations unless the planned deployment passes the coordination process. It should be noted that Ofcom will not be able to enter into detailed discussion or offer additional services in relation to base station coordination. We will provide a pass/fail for each base station processed through the coordination tool and the margin in relation to the coordination threshold.
- 9.12 The draft coordination notice for new licensees is set out at annex 24. The annex presents the current list of registered band user locations which would need to be protected, based on the information we hold at the date of this consultation. However, we note we are

continuing to engage with fixed links licensees with the aim of migrating fixed links operations to alternative frequencies or technologies by June 2020 where possible. This may mean that some of the proposed protections as set out in the annex may become redundant by the time of the award. We will update the list of protection requirements in the Information Memorandum for the award.

- 9.13 It will not be practical for Ofcom to process individual base stations, one at a time, through the coordination tool. Therefore, we are proposing that, unless agreed beforehand, 3.6-3.8 GHz spectrum access licensees will be required to submit technical details in batches of at least 100.
- 9.14 It is more efficient for Ofcom to process larger batch sizes; therefore, licensees will be encouraged to submit batches that are as large as possible. Submitting multiple small batches is likely to result in slower processing through the coordination tool and may lead to delays in Ofcom providing results.
- 9.15 In general, we note that new base station deployments within 50 km of the registered band user locations shown in annex 21 are particularly at risk of failing the coordination process – though we don't expect all base station within this distance to be problematic. It is anticipated that the vast majority of base stations further than 50 km will successfully pass coordination and base station deployment is unlikely to be significantly affected beyond this distance.
- 9.16 In annex 15 we have estimated the impact that coordination might have in the vicinity of the fixed link between the Isle of Wight and Portsmouth. We conclude that within a radius of 50 km roll-out of base stations is likely to be difficult, with about 80% of the sectors we analysed failing to meet the protection criteria for this fixed link.
- 9.17 For base stations further away, roll-out is likely to be minimally affected with about 4% sectors analysed that lie within a few kilometres either side of the extended baseline of the fixed link (out to 200 km) failing to meet the protection criteria for the link – however, in this case the failure margin is relatively small (median margin ~3 dB) implying that with reasonable mitigation (e.g. reducing powers or careful pointing) most of the sectors that failed (in our analysis) could in fact be deployed with minimal impact on network performance.

In-band restriction zones around satellite earth stations in 3.6-3.8 GHz

- 9.18 In our October 2017 statement we said that satellite earth stations (SES) could continue to operate in the band on a licence exempt basis following the end of notice periods (while noting that their ability to continue to receive without suffering interference that might adversely affect their service could vary between sites). We said we would explore the possibility of applying localised restrictions in future licences to facilitate continuing operation of satellite services in the 3.6-3.8 GHz band, where these would not have a material impact on mobile deployment.

- 9.19 We have since communicated with satellite earth station operators to understand their interest in exploring this option. To date, two operators have expressed an interest in restriction zones around their SES sites.
- 9.20 We consider that restriction zones with a radius of 1 km would provide some degree of reassurance for these operators that mobile base stations using the 3.6-3.8 GHz band will not be situated directly next to their SES sites, while meeting our objective to ensure that any constraints to mobile deployment should be kept to a minimum and should not prevent MNOs from offering mobile services in the area affected.
- 9.21 We present the proposed restriction zones in Figure 9.2 below.

Figure 9.2: Proposed restriction zones

Location (central point of 1km zone)	Signal level threshold
Whitehill - SP 47862 18634	-43 dBm/5 MHz
Woofferton - SO 50930 68253	-43 dBm/5 MHz

- 9.22 New licensees wishing to deploy base stations within these restriction zones will need to plan their deployments to respect the relevant threshold level shown in the table.
- 9.23 We propose that, for any base station within a restriction zone, the licensee will be required to ensure that the calculated signal power at the SES location within any 5 MHz portion of the operating bandwidth of the SES is no greater than the signal level indicated above. The power level at the SES receiver must be calculated assuming free space path loss. Outside the restriction zones, no such constraints will apply.
- 9.24 The restriction zones will be included in a notice attached to new licences. The draft notice is presented at annex 25.

Coexistence with users in the 3.8-4.2 GHz band

- 9.25 In our October 2017 statement, we provided a summary of our preliminary analysis looking at the risks of adjacent band coexistence issues between new services in the 3.6-3.8 GHz band and existing satellite and fixed link assignments above 3.8 GHz. We said that the potential interference risks are likely to be limited to small areas around earth stations or along the path of fixed links operating above 3.8 GHz, and that there are a range of methods that could be used to mitigate these risks. We noted that we were continuing our analysis of adjacent band coexistence issues and would consult on our findings in 2018.
- 9.26 We have now completed further technical analysis and present our findings in this section of the consultation. In the following paragraphs, we first provide an overview of our approach to the analysis and the assumptions we have used. We then present the results of our adjacent band coexistence assessment, for both satellite earth stations and fixed links in the 3.8-4.2 GHz band. Finally, we discuss policy options and our proposed

approach. We note that more detailed modelling results are presented in annex 15.
 Technical conditions relating to the 3.8 GHz boundary

- 9.27 We discuss our proposed technical conditions relating to the 3.6-3.8 GHz band in section 11. As explained in more detail there, these conditions have been the subject of work in Europe. CEPT Report 67 provides out-of-band emissions limits above 3.8 GHz and we propose to include these limits in the 3.6–3.8 GHz licences.

Description of the technical analysis

- 9.28 Our technical analysis assesses the interference risk from mobile networks directly below 3.8 GHz into satellite earth stations (SES) and fixed links (FL) operating above 3.8 GHz.
- 9.29 There are two possible causes of interference for both SES and FL:
- a) 5G equipment out-of-band emissions – from 5G equipment deployed in the 3.6-3.8 GHz band whose out-of-band/unwanted emissions fall in the pass-band of the earth station /fixed link receiver above 3.8 GHz.
 - b) SES and FL receiver blocking – caused by high power 5G signals saturating the victim receiver. Receivers operating in close proximity to LTE transmitters may be susceptible to high power LTE transmissions in adjacent channels which can overload the receiver front end if the receiver does not have sufficient adjacent channel selectivity.
- 9.30 In our analysis we have focused primarily on the potential for out-of-band emissions from new mobile equipment to degrade the performance of receivers operating above 3.8 GHz. As noted in our October 2017 statement, additional filtering at the receiver will be an effective mitigation for managing coexistence risks related to out-of-band receiver selectivity and blocking, and existing users should consider whether this is needed on a case by case basis.

Assumptions and methodology

- 9.31 The assumptions for the operating technical conditions (transmit power and emission masks) of macro cells used in our analysis are based on the draft ECC Report 281²³⁹ and draft CEPT Report 67.²⁴⁰ The AAS antenna pattern for macro cells is based on ITU-R M.2101.²⁴¹
- 9.32 The interference risk to existing users is assessed against the current technical licence conditions derived from ITU-R SF.1006²⁴² for SES and Ofcom’s Technical Frequency Assignment Criteria (TFAC) for FL.²⁴³

²³⁹ ECC PT1 (18) 099 Annex 22 - Draft ECC Report 281 on C-band after PC <https://www.cept.org/ecc/groups/ecc/ecc-pt1/client/meeting-documents/>

²⁴⁰ ECC PT1 (18) 099 Annex 16 – Draft CEPT Report 67 on C-band after PC <https://www.cept.org/ecc/groups/ecc/ecc-pt1/client/meeting-documents/>

²⁴¹ https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2101-0-201702-I!!PDF-E.pdf

²⁴² https://www.itu.int/dms_pubrec/itu-r/rec/sf/R-REC-SF.1006-0-199304-I!!PDF-E.pdf

²⁴³ https://www.ofcom.org.uk/_data/assets/pdf_file/0017/92204/ofw446.pdf

- 9.33 We assessed the interference risk using two approaches. In the first approach we carried out an 'area-analysis', i.e. we assessed the interference risk from a hypothetical base station (BS) in a given location. We then moved the BS in a grid of points around each SES and FL. We considered the same deployment characteristics (e.g. transmit power, height, beam pointing with respect to the receiver's main lobe, etc.) for each point of the grid.
- 9.34 In the second approach, we modelled a simulated future UK-wide 5G macrocell deployment, based on an updated understanding of the likely characteristics of potential 5G networks at 3.6-3.8 GHz band. In both approaches, we used a 50m terrain database and a clutter database at the transmitter, receiver and along the interfering path to model the signal propagation.
- 9.35 For the area analysis, we assumed two different scenarios. In the first, worst-case, scenario, we assumed that the BS was pointing towards the boresight of the earth station receiver, transmitting with the maximum permitted EIRP of 65 dBm/5 MHz.
- 9.36 In the second scenario, we assumed a set of more realistic operational parameters for 5G BS. These included small offsets in elevation and azimuth pointing as well as lower EIRP levels, i.e. values that were more in line with what we observe in real mobile network deployments.
- 9.37 We present a summary of our modelling results below, with more detailed modelling results presented in annex 15.

Satellite Earth Stations

- 9.38 There are currently 16 sites with satellite earth stations which have frequency assignments either wholly or partly in the 3.8-4.2 GHz band; 12 of these sites are operating under a Permanent Earth Station (PES) licence and 3 sites are operating with grants of RSA for ROES.²⁴⁴ One site has both a PES licence and a grant of RSA for ROES.
- 9.39 We conducted our analysis on four of the satellite earth stations operating directly above the 3.8 GHz boundary as these are the sites which would potentially be affected by out-of-band emissions from new mobile services in the 3.6-3.8 GHz band. Of the 16 SES sites in the band, 10 have frequency assignments which currently straddle the 3.8 GHz boundary. Following the removal of existing 3.6-3.8 GHz authorisations as described earlier, these frequency assignments will be amended so that they only include frequencies from 3.8 GHz upwards.
- 9.40 Our analysis was based on the technical conditions included in existing satellite earth station licences and the technical licence conditions proposed by CEPT for 5G base stations equipped with Active Antenna Systems (AAS) and non-AAS.
- 9.41 In our area analysis, under the worst-case scenario, we found that the interfering BS sectors could be located at a maximum distance of about 4.1 km or less for non-AAS macro cells, and about 7.5 km or less for AAS macro cells.

²⁴⁴ Recognised Spectrum Access for Receive-only earth stations

- 9.42 In the more realistic scenario, we found that the interfering BS sectors could be located at a maximum distance of 2.25 km or less for non-AAS macro cells and 2.5 km or less for AAS macro cells. These separation distances are not equal in all directions from the earth station receiver; they are affected by the geography of the area as well as the pointing of the receiver and represent the maximum separation distances of the interfering contour.²⁴⁵
- 9.43 In our UK-wide macrocell analysis, we looked at the effect of long term²⁴⁶ single entry and aggregate interference as well as short term²⁴⁷ interference due to anomalous propagation. When looking at long-term interference (including long-term aggregate interference), we found that between zero and three BS sectors were predicted to have the potential to cause interference. When looking at short-term interference, we found that between zero and six BS sectors could have the potential to interfere.

Fixed Links

- 9.44 Our fixed links analysis considered the existing fixed links in channel 8 (centre frequency 3830 MHz, bandwidth 30 MHz), which, following the closure of channels 4 to 7 and the removal of existing fixed links in these channels, will be the fixed link channel closest to the 3.8 GHz boundary. Currently there are nine fixed link frequency assignments in channel 8.
- 9.45 The analysis was based on the technical conditions included in fixed link licences, and the technical licence conditions proposed by CEPT for 5G base stations equipped with Active Antenna Systems (AAS) and non-AAS.
- 9.46 In our area analysis, under the worst-case scenario, we found that the maximum separation distances between interfering BS and the FL receiver were relatively large, e.g. for one fixed link in our analysis, the maximum separation distance was approximately 40 km for both for AAS and non-AAS systems. In the more realistic scenario, distances were somewhat reduced. However, due to the high directionality of the fixed link receiving antennas, the width of the impacted areas in both scenarios were very narrow.
- 9.47 In our UK-wide macrocell analysis, we looked at scenarios where BS emissions only just met the ECC mask (for both non-AAS and AAS systems) and a more realistic case where BS emissions meet a mask which we derived from data received from various equipment manufacturers.
- 9.48 In the worst case, using the ECC mask for AAS systems and looking at the short-term single-entry interferers case, between one and 102 sectors were predicted to have the potential to cause interference. Using the more realistic mask however, this number was reduced to between nought and seven sectors. Full details are presented in annex 15.
- 9.49 In addition, we note that in practice, fixed links may not be subject to interference even in situations where our analysis suggests it is possible. This is because the parameters used in

²⁴⁵ In this section we use the term ‘interfering contour’ to describe the geographic area within which a BS could cause interference.

²⁴⁶ Long term interference describes interference conditions for a receiver that will occur most of the time.

²⁴⁷ Short term interference describes the conditions when the interfering signal is being enhanced for short periods of time. Short-term interference usually occurs when atmospheric conditions lead to anomalous propagation.

calculating the threshold for fixed links interference include a conservative margin to account for fading of the fixed links signal (e.g. due to anomalous atmospheric conditions).

Options for managing coexistence with services above 3.8 GHz

- 9.50 As discussed earlier in this section, the technical conditions at the 3.8 GHz boundary are set out in CEPT Report 67 and ECC Report 281 and we expect there will be an EC Decision on the conditions towards the end of 2018 or the beginning of 2019. We have considered whether it is necessary to take any additional actions at a national level to further mitigate the risk of interference from new services in 3.6-3.8 GHz to existing services above 3800 MHz.
- 9.51 Options that we have considered include a) doing nothing, b) setting more restrictive out-of-band limits at the 3.8 GHz boundary and c) including coordination requirements in new licences.
- 9.52 In option b, setting more restrictive out-of-band limits at the 3.8 GHz boundary would mean that mobile base station equipment for use in the 3.6-3.8 GHz band in the UK would be subject to stricter conditions than the rest of Europe. This could result in manufacturers needing to produce UK-specific models of base station equipment which could either directly increase equipment costs and/or reduce the choice of equipment available to operators.
- 9.53 There are currently just a small number of existing users operating above the 3.8 GHz boundary, and these operate across a limited geographical area. We therefore consider that setting more restrictive out-of-band limits at the 3.8 GHz boundary would not be a proportionate response to this risk.
- 9.54 Turning to option c, in general it is not our policy to impose coordination requirements in relation to adjacent band coexistence issues except in exceptional circumstances. This approach is consistent with our approach in previous spectrum releases, e.g. for the 2.3 and 3.4 GHz award, where we considered the risk to satellites operating above the 3.6 GHz boundary.²⁴⁸
- 9.55 For this case, as noted above, there are a small number of users using the spectrum immediately above the 3.8 GHz boundary. Most of these users are in rural areas where the density of mobile sites is likely to be lower and where there is likely to be more flexibility for mobile operators to adopt measures that reduce the probability of interference to adjacent spectrum users operating in close geographical proximity.
- 9.56 Also, whilst there is a small theoretical risk of interference to users operating above the 3.8 GHz boundary, in practice interference may not occur. This is because, even where we have considered more realistic scenarios, some of the parameters used in the modelling are still worst-case values. For example, as noted with relation to fixed links, the protection threshold includes a conservative fade margin.

²⁴⁸ https://www.ofcom.org.uk/__data/assets/pdf_file/0019/36037/updated-analysis.pdf

- 9.57 We therefore do not consider it necessary in this instance to impose out-of-band coordination requirements in new licences.
- 9.58 Our preliminary view is that we do not need to include any specific conditions in licences to mitigate the risk of interference. We note that all Wireless Telegraphy licences include conditions which stipulate that Ofcom *may “require radio equipment (or any part thereof) to be modified or restricted in use, or temporarily or permanently closed down immediately if in the opinion of the person authorised by Ofcom the use of the radio equipment is, or may be, causing or contributing to undue interference to the use of other authorised radio equipment”*.
- 9.59 If stakeholders have any specific concerns about this option, we invite them to explain why they consider that other options would be more appropriate.

Consultation questions

Question 9: Do you agree with our proposed approach to managing interim protections for registered 3.6-3.8 GHz band users?

Question 10: Do you agree with our 3.6-3.8 GHz in-band restriction zone proposals?

Question 11: Do you agree with our preliminary view that we do not need to include any specific conditions in 3.6-3.8 GHz licences to mitigate the risk of adjacent band interference?

10. Non-technical licence conditions

- 10.1 In this section we set out the non-technical licence conditions that we propose to include in the licences to be issued after the award of the 700 MHz and 3.6-3.8 GHz bands. The following section (section 11) considers the technical licence conditions, such as power levels and measures to avoid interference.
- 10.2 Licences will contain the minimum necessary restrictions on the permitted use of the spectrum bands to avoid harmful interference, and to ensure compliance with our statutory duties and international obligations.
- 10.3 Given the similar nature of the service(s) likely to be rolled out in these bands, many of the non-technical licence conditions will be the same or similar for licences awarded in each band. Where there are differences we will highlight them. Copies of the proposed licences can be found in annexes 22 and 23 of this document.
- 10.4 This section discusses the proposed non-technical licence conditions relating to the following areas:
- licence commencement and duration;
 - the duration of the initial period, our limited rights for revoking the licence during this period and any additional powers we have following the initial period;
 - the territorial extent of licences;
 - the payment of licence fees;
 - making the Wireless Telegraphy licences tradable in secondary markets;
 - non-technical restrictions;
 - sharing of spectrum;
 - roll-out obligations;
 - access and inspection;
 - modification, restriction and closedown; and
 - provision of information to promote efficient use of spectrum.
- 10.5 We are also setting out proposals for improving mobile coverage and protecting digital terrestrial television, both of which would be implemented through licence conditions. We discuss these conditions in sections 8 and 9.

Licence commencement and duration

- 10.6 Consistent with previous spectrum awards carried out by Ofcom – including the 2018 auction of spectrum in the 2.3 and 3.4 GHz bands – we propose that the licences to be auctioned should be:
- issued for an indefinite duration;

- issued soon after the conclusion of the award, when winning bidders have made any outstanding payments to cover their licence fees (the licence fee for the initial period will be as determined through the award process);
- issued for an initial period of 20 years starting from the date of issue in the case of the licences in the 3.6-3.8 GHz bands and from a later date of commencement (likely in Q2 2020) in the case of the licences in the 700 MHz band (reflecting that clearance of that band will not be complete and the band will not be available for use for mobile services until then). We consider the initial operational term of a licence should be long enough to earn an appropriate return on investment, and believe 20 years is consistent with this consideration;
- revocable before the expiry of the initial period only on certain limited grounds (i.e. at the request or with the consent of the licensee; for non-payment or late payment of the relevant licence fee; for breach of any of licence terms; for breach of auction regulations; for breach of trading regulations; for national security or to comply with international agreements; or under direction of the Secretary of State);
- revocable from any point after the expiry of the initial period on the grounds set out above and, additionally, for spectrum management reasons, subject to five years notice. Once the initial period has expired, the licence will remain in force and continue to be held by the licensee. However, there may be circumstances in which regulatory intervention is justified in the public interest (for example, to overcome a specific market failure). A power to take regulatory action, if justified, will be achieved by us having the power to revoke the licence on spectrum management grounds after the end of the initial period.

Territorial extent of licences

- 10.7 We propose to award the licences for the 700 MHz and 3.6-3.8 GHz band on a UK-wide basis. However, they will not extend to the Channel Islands and the Isle of Man. Licences in the 3.6-3.8 GHz band will not extend to UK territorial waters. This is consistent with licences in the 3.4 GHz licences, awarded after the 2018 auction.
- 10.8 We considered whether we should instead award local or regional licences. However, we have provisionally concluded that awarding national licences would be most likely to achieve optimal use of the spectrum.
- 10.9 This is primarily because both the 700 MHz and the 3.6–3.8 GHz bands have properties that make them particularly suitable for mobile broadband use, for which we expect there to be national demand. We think that the most efficient way to meet this demand will be through a UK-wide award of national spectrum licenses, allowing the MNOs and/or other bidders to offer UK-wide services.
- 10.10 A more detailed assessment of alternative potential uses of the spectrum and alternative licensing models (e.g. regional licensing) is set out in annex 5 of this document.

The payment of licence fees

- 10.11 The licences will be subject to a provision that will enable Ofcom to impose an on-going additional annual fee after the expiry of the initial period.
- 10.12 The mechanism and level of annual fees after the initial licence term will depend on our general approach to the use of this spectrum at the time, and how that general approach relates to these licences and to our statutory duties. Prior to any imposition of fees, we would consult as appropriate and give notice of our specific proposals, before any fees are introduced.

The tradability of licences

- 10.13 We propose to make the award licences tradable by amending the Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011 (the “Mobile Trading Regulations”) to include the new frequency bands of the 700 MHz and 3.6-3.8 GHz frequencies.
- 10.14 In line with Ofcom’s policy, and in accordance with the provisions of the Mobile Trading Regulations, we propose that the licences will be tradable, but not leasable. This is the same as other licences covered by the Mobile Trading Regulations. However, as set out in our 2016 review of spectrum sharing, we will keep this position under review and consider extending leasing if there are likely to be net benefits, including sufficient evidence of demand to lease spectrum.
- 10.15 Early next year, we plan to give formal notice of our proposals for amending the Mobile Trading Regulations, including the draft regulations that we propose to make to amend these regulations.

Spectrum sharing

- 10.16 We note that licences issued by Ofcom do not guarantee exclusive use of the spectrum awarded. In the future, we may grant additional authorisations to allow the use of all, or part, of the spectrum, including the spectrum that is the subject of this award process. We have published a document alongside this consultation setting out our proposals for spectrum sharing in future.²⁴⁹

Non-technical restrictions on use

- 10.17 We do not propose to impose any non-technical restrictions in the licences which limit the use to which the 700 MHz and 3.6-3.8 GHz spectrum could be put (such as specifying the type of service that should be offered, the technology that should be deployed or the equipment that should be used).

²⁴⁹ <https://www.ofcom.org.uk/consultations-and-statements/category-1/enabling-opportunities-for-innovation>

Use-it-or-lose-it

- 10.18 We have considered whether or not to apply licence conditions requiring spectrum holders who acquire spectrum in the 700 MHz and 3.6-3.8 GHz bands to make use of the frequencies in a timely manner - or risk having them taken away (i.e. 'use-it-or-lose-it').
- 10.19 We do not currently propose to include such conditions, for a number of reasons:
- Such conditions are very difficult to make workable in practice because of the problem of defining what constitutes 'use' and therefore what the trigger for an enforced trade or revocation would be;
 - There may be entirely legitimate reasons for spectrum remaining unused – the licensee may be holding back until it sees a suitable commercial opportunity or until the technology it wishes to use is ready;
 - Imposing such an obligation also has the potential to distort and/or chill the incentives to invest in the spectrum, and so reduce the benefits for consumers and citizens which the award would otherwise create.
- 10.20 In any case, as noted above under 'Spectrum sharing', licences issued by Ofcom are not exclusive, and we have discretion to authorise use of these or any other frequencies, for other purposes, in line with our statutory duties.
- 10.21 We understand that the Government is considering legislating to require the inclusion of 'use-it-or-lose-it' conditions in new spectrum licences, as part of its proposed implementation of the European Electronic Communications Code (the Code). We will keep this under review and to the extent we are required to include such a condition in the licences we auction when we make our final decisions, we will do so.

Roaming

- 10.22 We do not rule out the possibility of looking to impose roaming conditions, as appropriate, in 700 MHz licences in the future, noting in particular that these are licences of at least 20 years' duration.
- 10.23 We propose to include this point in the Information Memorandum for this award, so that all bidders will be aware that this is a possible option that we might wish to consider in the future. Any future proposals to impose roaming obligations would be subject to detailed analysis and consultation at the time, in line with our general approach.

Access and inspection

- 10.24 In accordance with our standard spectrum licence conditions, we propose that licensees should be required to permit any person authorised by Ofcom to have access to and to inspect the radio equipment specified in the licence at all reasonable times.

Modification, restriction and closedown

- 10.25 In line with standard provisions, we propose a licence provision permitting Ofcom to require that the radio equipment (or any part of it) be modified, restricted in use or temporarily or permanently closed down if a licensee breaches the terms of its licence; the use of radio equipment is or may be causing or contributing interference to the operation of other authorised radio equipment; or it appears necessary or expedient in the event of a national or local state of emergency.

Provision of information to facilitate optimal spectrum use

- 10.26 In line with our duty to manage the spectrum efficiently, we propose to include a condition in the licences requiring licensees to provide, on request, general information regarding their equipment and use of frequencies, or the roll-out of their network.
- 10.27 Provision of this information could help identify areas where other companies might wish to provide additional services. If appropriate, it could be open to others to gain access to spectrum in those areas by trading with licensees. This would help secure optimal use of the spectrum.
- 10.28 We note that we have powers under both the Communications Act 2003 (section 135 to 146) and the WT Act (sections 32 to 34) to require third parties to provide us with information in certain circumstances. However, we consider that there remains a benefit in requiring licensees to compile and maintain basic details relating to the radio equipment that they are using pursuant to the licence so that it is readily available in the event that it is needed, for example, in cases of alleged interference.
- 10.29 We also propose to include more specific requirements in this regard in the licence(s) to use the 700 MHz centre gap frequencies (733–758 MHz). The reasons are as follows.
- 10.30 In the period immediately before the commencement of the licence(s), these frequencies will be licensed for use by Arqiva to provide interim DTT multiplexes.²⁵⁰ Since we decided in October 2016 to make the 700 MHz band available for use for mobile services from June 2020, we served notice of revocation of Arqiva’s licence, to be effective on 21 June 2020.
- 10.31 However, we also said, as part of our October 2016 decision, that if the parties to whom the centre gap frequencies are awarded for mobile services do not deploy services immediately, we were minded to allow the interim multiplexes to remain in the centre gap until the mobile licensee(s) switch on their services. That remains our position. If there is a lack of demand by the mobile licensee(s) to use the spectrum such that Arqiva could continue to use it for the interim multiplexes, we intend that it could do so.

²⁵⁰ These are DTT multiplexes that broadcast Freeview programme channels using spectrum frequencies that were available only for a limited period. Originally, they used the 600 MHz band which was temporarily vacant. As part of the clearance of DTT services from the 700 MHz band, Ofcom is moving the other DTT multiplexes (which broadcast most Freeview channels) from there into the 600 MHz band. In consequence, the interim multiplexes are being moved temporarily into the centre gap of the 700 MHz band.

10.32 As we decided to make the spectrum available for mobile services from June 2020, and the auction winners will have the right to use it from that time in accordance with that decision, and we are not re-opening that decision, the terms on which Arqiva may continue to use the centre gap are necessarily limited. We propose that it could do so on this basis:

- under a new licence which we would grant to it to run from 21 June 2020 for a duration it would agree with the relevant mobile licensee(s)²⁵¹ and subject to fees that would be a pro-rating of the fees that applied under Arqiva's existing licence (which ends on 21 June 2020);
- on a non-interference and non-protected basis – that Arqiva:
 - may not cause interference to any other services (such as mobile services or services in neighbouring countries), and may be required to switch-off the interim multiplex services if it does so; and
 - would be responsible for resolving interference from mobile services to the DTT services provided by the interim multiplexes (which would not fall within the mobile licensees' co-existence obligations as proposed in chapter 9 above); and
- would be required to communicate with viewers, as directed by Ofcom, when the interim multiplex services are terminated.

10.33 The first of those proposed terms would, in our provisional assessment, strike an appropriate balance between each of the following points, and secure optimal use of the spectrum:

- the rights of the auction winner(s) to use the spectrum for mobile services from Q2 2020;
- the fact that the the auction winner(s) know when, how and where they intend to use the spectrum and can therefore reach an appropriate agreement with Arqiva;
- the provision to Arqiva of sufficient tenure and certainty that it will make use of the spectrum for the DTT interim multiplexes; and
- the limit of the risk that the spectrum would be unused for a period.

10.34 It will be necessary for Arqiva to provide us with evidence of any agreement(s) it reaches with the auction winner(s) so we can issue it with an appropriate licence.

10.35 It will also be necessary to impose conditions on the 700 MHz centre gap mobile licensee(s) in this connection. We propose to require them to give us three months'²⁵² advance notice of when, how and where they intend to start using the spectrum. That would enable us to decide whether and when to serve notice of revocation of any relevant licence on Arqiva.

²⁵¹ If the mobile licensee(s) had not switched on their services but Arqiva was unable to reach an agreement with them, we would be minded to grant Arqiva licences one month at a time subject to notice from the mobile licensee(s) of intended use of the spectrum. The first licence would start on 21 June 2020.

²⁵² Or such other period as we may determine. Such as, for example, requiring them to give us a period of notice equivalent to half of the fixed-term of any licence granted to Arqiva.

Coverage obligations

- 10.36 As set out in Section 4, we propose to offer coverage obligations in the award. If any bidder wins a coverage obligation in the award, a coverage obligation would be included in any spectrum licences that they win as part of this award. The proposed wording of the coverage obligation is set out in Annexes 22 and 23.

Consultation question

Question 12: Do you agree with the non-technical conditions that we propose to include in the licences to be issued after the award of the 700 MHz and 3.6-3.8 GHz bands?

11. Technical licence conditions

- 11.1 This section discusses the technical conditions we propose to include in the licences issued after the award of the 700 MHz and 3.6-3.8 GHz bands to ensure we impose the minimum necessary restrictions on the permitted use of the spectrum bands to avoid harmful interference, and to ensure compliance with our statutory duties and international obligations.
- 11.2 CEPT project team ECC PT1 has reviewed various aspects of the 3.4-3.8 GHz technical conditions for their suitability for 5G technologies.²⁵³ We expect the results of CEPT work, including the additional block-edge-masks specified in CEPT Report 67 for new active antenna systems, to be included in an amendment to the 3.4-3.8 GHz EC Decision,²⁵⁴ by the time of the award.
- 11.3 Our proposals reflect the changes that we currently expect to be made to that EC Decision. If the amendment to the 3.4-3.8 GHz EC Decision is finalised before we make our final decisions, we will consider whether it would be appropriate to make any changes to the licence conditions that we are proposing in light of the amended EC Decision.
- 11.4 Our general approach has been to draft the 700 MHz licences using a similar format to the existing 800 MHz licences, and to draft the 3.6-3.8 GHz licences using a similar format to the existing 3.4 GHz licences. The draft licence condition clauses for 700 MHz and 3.6-3.8 GHz are set out in annexes 22 and 23 respectively.
- 11.5 We have drafted interface requirements (IRs) for 700 MHz and 3.6-3.8 GHz and these are set out in in annexes 20 and 21 respectively.
- 11.6 This section is organised as follows:
- a summary of the main technical conditions that would be common to both the 700 MHz and 3.6-3.8 GHz licences, including our proposed approach to international cross-border coordination.
 - other technical conditions that would be specific to the 700 MHz licences; and
 - other technical conditions that would be specific to the 3.6-3.8 GHz licences.

Technical licence conditions that would be common to the 700 MHz and 3.6-3.8 GHz licences

- 11.7 We set out below the main technical conditions that we propose to include in both the 700 MHz and 3.6-3.8 GHz licences, highlighting where we have taken a different approach in similar licences (e.g. the 800 MHz and 3.4 GHz licences respectively).

²⁵³ The relevant documents are CEPT Report 67 and ECC Report 281 and a revision to ECC Decision (11)06 based on these reports has been approved by ECC. The amendment to the 3.4-3.8 GHz EC Decision (2014/276/EU) has been agreed by RSC (to update the technical conditions in line with CEPT Report 67) and we expect it to be published in the OJ early next year (2019). We note that ECC recently consulted on the CEPT 3.4-3.8 GHz synchronisation toolbox report.

²⁵⁴ See Decision 2014/276/EU amending Decision 2008/411/EC on the harmonisation of the 3 400-3 800 MHz frequency band for terrestrial systems capable of providing electronic communications services in the Community.

11.8 In the 700 MHz and 3.6-3.8 GHz licences, we propose to update the requirements for the recording of radio equipment deployments by licensees to reflect changes in technology and the way radio equipment is deployed.

We propose to require radio equipment records to at least 10m resolution

a) There is currently a range of radio equipment location accuracy requirements across our mobile spectrum access licences. For the new 700 MHz and 3.6-3.8 GHz licences we believe that a 10m resolution is both suitable for spectrum management purposes and can reasonably be achieved by licensees, for example, using GPS.

We propose not to require postal address records for femtocells and repeaters

b) The address of femtocells and repeaters may not always be accurately recorded. For example, a user may move home and take their femtocell or repeater with them or may get their femtocell or repeater delivered to a location but choose to use it elsewhere. Therefore, we propose that the new 700 MHz and 3.6-3.8 GHz licences would not require the licensees to compile and maintain accurate written records in respect of femtocell and repeaters.

11.9 We propose to define emissions limits on a ‘per antenna’ or a ‘per cell’ basis in line with the language used in CEPT Report 67 and the way we are proposing to define these terms can be seen in our draft licences.

Cross-border coordination

11.10 We propose that both the 700 MHz and 3.6-3.8 GHz licences would require compliance with cross-border coordination procedures notified to the licensees by Ofcom. We have worked with neighbouring administrations to establish memoranda of understanding for cross-border coordination. To date, the UK has agreed to the following coordination procedures with neighbouring countries: ²⁵⁵

- a Memorandum of understanding (MoU) on frequency coordination between France and the United Kingdom concerning the spectrum coordination of land mobile radiocommunication networks in the frequency range 703-2690 MHz to be applied in the area of the Channel Islands and France;
- a MoU on frequency coordination between France and the United Kingdom concerning the spectrum coordination of land mobile radiocommunication networks in the frequency range 703-2690 MHz to be applied in the area main land area;
- a MoU on frequency coordination between France and the United Kingdom concerning the spectrum coordination of land mobile radiocommunication networks in the frequency bands 2300-2400 MHz and 3400-3800 MHz to be applied in the area including France, the United Kingdom and the Channel Islands; and

²⁵⁵ International coordination is carried out between administrations using the framework provided in ECC Recommendation 15(01). For the details of the existing MoUs see: International Coordination, Ofcom, <https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/mobile-wireless-broadband/international-coordination>

- a MoU on frequency coordination between the Republic of Ireland and the United Kingdom for wireless access services in the frequency band 3400-3800 MHz.

11.11 We are also in the process of agreeing an MoU with the Republic of Ireland in relation to the 700 MHz band.

700 MHz Technical licence conditions

The 700 MHz band is harmonised for mobile broadband services

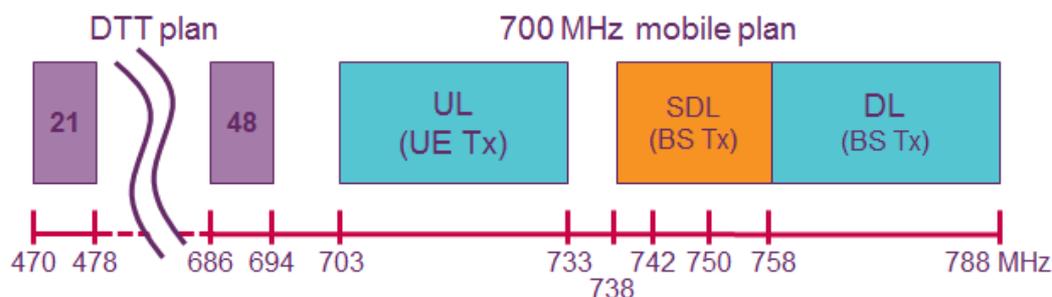
11.12 The European Commission published its final Decision (EU) 2016/687 on the harmonisation of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union (the '700 MHz Commission Decision')²⁵⁶ in April 2016.

11.13 The 700 MHz Commission Decision sets out the technical conditions that EU Member States must apply if they make the 700 MHz band available for mobile use. A key requirement is that Member States must adopt the paired band plan and block edge masks for the use of 703-733 MHz paired with 758-788 MHz. The decision also includes several options for the 733-758 MHz "centre gap", including a band plan and block edge mask for 20 MHz of downlink-only use.

Harmonised technical conditions for 700 MHz paired and downlink-only spectrum

11.14 We have decided to award the 700 MHz band with 703-733 MHz paired with 758-788 MHz and downlink-only in 738-758 MHz as shown below.

Figure 11.1: The band arrangement after the 700 MHz award



11.15 We propose an in-block base station power limit of 64 dBm/(5 MHz) EIRP per antenna. This is in line with the 700 MHz Commission Decision which does not set a mandatory in-block downlink power limit but states that: "In case an upper bound is desired by an

²⁵⁶ "Commission Implementing Decision (EU) 2016/687 of 28 April 2016 on the harmonisation of the 694-790 MHz frequency band for terrestrial systems capable of providing wireless broadband electronic communications services and for flexible national use in the Union",

<https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AAOJ.L.2016.118.01.0004.01.ENG>

administration, a value may be applied, which does not exceed 64 dBm/(5 MHz) per antenna.”

11.16 We believe that this is limit would provide adequate protection for adjacent DTT services. We note that this power limit is higher than in the 800 MHz licences (61 dBm/(5 MHz) EIRP per cell) and slightly different to the power limit in the 900 MHz licences (65 dBm/(5 MHz) EIRP per Radio Equipment).

11.17 The power limits on out-of-block and out-of-band emissions that we propose are set out in paragraphs 8 and 9 of Schedule 1 to the draft 700 MHz licences (see annex 20) and are in line with the 700 MHz Commission Decision. We note that the 700 MHz Commission Decision gives us some flexibility on defining the emissions limits and measurement bandwidth. We discuss our proposals, taking this flexibility into account, next.

We propose a 5 MHz measurement bandwidth for the uplink and downlink band emissions limits

*703-733 MHz
738-788 MHz*

a) The 700 MHz Commission Decision provides several measurement bandwidth options for assessing out-of-block emissions limits of the 700 MHz uplink and downlink. The measurement bandwidth depends on the width of the block to be protected.²⁵⁷ We are planning to award the 700 MHz band in lots of 5 MHz bandwidth. Therefore, any new licensees in the 703-788 MHz band will have a minimum block size of 5 MHz.

In light of this, we believe it would be appropriate to adopt a 5 MHz measurement bandwidth for out-of-block emissions in both the uplink band (703-733 MHz) and the downlink band (738-788 MHz)

²⁵⁷ 700 MHz Commission Decision: “For blocks of 5 MHz or greater, the measurement bandwidth shall be 5 MHz. Administrations may select a measurement bandwidth of 3 MHz or 200 kHz for protection of a block size of 3 MHz depending on the national implemented options.”

We propose to use the transitional power limits in the 5 MHz which is not part of the award

733-738 MHz

b) In line with the 700 MHz Commission Decision, we propose to apply the transitional power limits in the 5 MHz of the centre gap that is not part of the award (733-738 MHz).

We note that the 700 MHz Commission Decision gives administrations flexibility in setting more stringent out-of-band emissions limits for 733-736 MHz if they intend to award spectrum for FDD base stations supporting PPDR²⁵⁸ or M2M²⁵⁹ technologies using 733-736 MHz for the uplink and 788-791 MHz for the downlink. At this time, we do not have any firm plans for FDD PPDR or M2M using this particular frequency arrangement.

We propose a 3 MHz measurement bandwidth for the transitional power limits above 788 MHz

788-791 MHz

c) We believe that base station transitional power limits in the 800 MHz guard band (788-791 MHz) should be considered over a measurement bandwidth of 3 MHz. This is because we are not aware of any reason why a higher resolution measurement bandwidth is necessary to prevent harmful interference.

- 11.18 The 700 MHz Commission Decision also specifies in-block and out-of-band emissions limits for uplink transmissions from licensed terminal stations. We propose to include the mandatory limits in our licences and we summarise our proposed emissions limits for licensed terminal stations below. These limits would not apply to the majority of consumer mobile devices, which will be operating under a separate licence exemption regime with its own set of technical conditions.

Figure 11.2: Summary of proposed 700 MHz uplink (703-733 MHz) power limits

In-block power limit	<i>Radio equipment</i>	<i>Maximum mean power limit*</i>
	Terminal station	23 dBm
Out-of-band power limit	<i>Frequency Range</i>	<i>Maximum mean power limit*</i>
	470–694 MHz	-42 dBm / 8 MHz
	694–698 MHz	-7 dBm / 4 MHz
	698–703 MHz	2 dBm / 5 MHz

* The power limits are specified as equivalent isotropically radiated power (EIRP) for terminal stations designed to be fixed or installed and as total radiated power (TRP) for terminal stations designed to be mobile or nomadic. The maximum mean power relates to the EIRP or TRP of a specific piece of Radio Equipment irrespective of the number of transmit antennas.

²⁵⁸ “Public protection and disaster relief (PPDR) radio communications” means radio applications used for public safety, security and defence used by national authorities or relevant operators responding to the relevant national needs in regard to public safety and security including in emergency situations.

²⁵⁹ “machine-to-machine (M2M) radio communications” means radio links for the purpose of relaying information between physical or virtual entities that build a complex ecosystem including the internet of Things; such radio links may be realised through electronic communications services (e.g. based on cellular technologies) or other services, based on licensed or unlicensed use of spectrum.

This value is subject to a tolerance of up to + 2 dB, to take account of operation under extreme environmental conditions and production spread.

- 11.19 The 700 MHz Commission Decision sets out certain non-mandatory limits for 733-758 MHz and provides that:
- 11.20 “The power limits have been derived from the spectrum emission mask specified in clause 4.2.3 of ETSI EN 301 908-13 v6.2.1, which means that LTE-based equipment will comply inherently with the emission limits specified in Table 11.”²⁶⁰
- 11.21 We do not believe it necessary to include such limits in the 700 MHz licences because the ETSI standards already provide an adequate spectrum emission mask for protecting other services.

No ‘cooperation clause’ in the 700 MHz licences

- 11.22 In the draft 3.6-3.8 GHz licences, we propose to include a clause which would require cooperation between licensees to prevent harmful interference between mobile networks. This would be in line with the approach that we took in in the 3.4 GHz licences because of the particular risk of inter-operator interference when operating TDD networks which are adjacent in frequency.
- 11.23 Our view is that it is not necessary to include a cooperation clause in the 700 MHz licences. This because there will be no TDD operation in the 700 MHz band and hence the particular risk of inter-operator interference when operating TDD networks which are adjacent in frequency does not arise in this case. Such a clause does not exist in current FDD licences.

3.6-3.8 GHz Technical licence conditions

The 3.4-3.8GHz band has been harmonised for mobile broadband services and 5G

- 11.24 In this sub-section, we summarise the recently proposed changes to the harmonised technical conditions in the 3.4-3.8 GHz band, noting that the EC decision has not yet been finalised. We consider the recent proposals across the whole 3.4-3.8 GHz band rather than the 3.6-3.8 GHz band alone because many of the recent harmonisation activities have considered technical conditions across the wider band.
- 11.25 In June 2016, the ECC undertook to review the suitability of the technical conditions in the 3.4-3.8 GHz ECC decision for new 5G services resulting in the development of CEPT Report 67 and ECC Report 281. These reports propose out-of-band baseline power limits for new mobile base station active antenna systems (AAS), taking into account coexistence with adjacent systems, and reclassified the existing limits to be for non-AAS only.
- 11.26 The reports also consider the out-of-block power limits suitable for AAS when assessing coexistence between mobile operators’ outdoor deployments. A separate report on

²⁶⁰ Explanatory note to Table 11, The 700 MHz Commission Decision

synchronisation including indoor deployments has recently been consulted on by CEPT project team ECC PT1.

- 11.27 The technical work on the block-edge-masks for AAS within CEPT is now mature and ECC has updated ECC Decision (11)06 with the proposals in CEPT Report 67. We also consider that the technical licence conditions proposed in CEPT Report 67 are likely to be adopted in an amended 3.4-3.8 GHz Commission Decision towards the end of this year or the beginning of next year. The further work on synchronisation is currently at an earlier stage and we expect the toolbox report to be accepted mid-2019.

Comparison with the 3.4 GHz licences

- 11.28 Since we awarded the 3.4 GHz licences in April 2018, new harmonisation conditions relevant to 5G systems have been developed in CEPT Report 67 and reflected in the amendment to ECC Decision 11(06). Below, we explain how we propose to take these recent developments into account in the 3.6-3.8 GHz licences.

New emissions masks for active antenna systems and updates to the emissions masks for non-AAS

- 11.29 Active antenna systems (AAS) are likely to be an important part of future mobile networks as they might significantly increase the spectral efficiency and network capacity by enabling massive MIMO.
- 11.30 CEPT Report 67 reviewed the technical licence conditions in 3.4-3.8 GHz for their suitability for 5G and the main recommendation was a new set of block-edge-masks (BEMs) for AAS.²⁶¹ These BEMs are defined in terms of total radiated power (TRP), which is different to the current emissions masks which are defined in terms of effective isotropically radiated power (EIRP).
- 11.31 As discussed in CEPT Report 67, a TRP limit is more appropriate for AAS than an EIRP limit. However, an EIRP limit remains appropriate for non-AAS. Below, we discuss the power limits that we propose to impose for both non-AAS and AAS, which are reflected in paragraphs 8, 10, 11 and 14 of Schedule 1 to the proposed 3.6-3.8 GHz licences (see annex 21).

The non-AAS limits are, mostly, the same as those in the 3.4 GHz licences a) Our proposed limits for non-AAS are the same as those in the 3.4 GHz licences, with the exception of the out-of-band limits below 3390 MHz and above 3.8 GHz, which we discuss in paragraphs d) and e) below.²⁶²

²⁶¹ We note that AAS is not an exclusively 5G technology and can also be used in 4G networks.

²⁶² See paragraphs 8, 10, 11 and 14 of Schedule 1 to the proposed 3.6-3.8 GHz licences.

- The AAS OOB limits are from CEPT Report 67**
- b) The out-of-block²⁶³ and out-of-band²⁶⁴ emissions limits that we propose for AAS are from CEPT Report 67.
- The AAS in-block limits are based on the non-AAS in-block limits in the 3.4 GHz licences**
- c) CEPT Report 67 does not mandate any in-block power limit for base stations. We have converted the non-AAS EIRP limit in the 3.4 GHz licences (65 dBm/(5 MHz) per cell) to a TRP limit for AAS (44 dBm/(5 MHz) per cell) by considering a typical sector antenna with 21 dBi gain.²⁶⁵ This in-block limit for AAS is appropriate for protecting other spectrum users because it is derived from the existing non-AAS power limits and so will have a similar impact on other users.
- We believe that the in-block power limit of 44 dBm/(5 MHz) TRP per cell will not be a material constraint on the ability of operators to deploy 5G. This is based on our review of the market which found that most 3.4-3.8 GHz AAS currently in development have a target power of 200 W.²⁶⁶
- The non-AAS limits below 3390 MHz have a different definition to the 3.4 GHz licences**
- d) CEPT Report 67 clarifies that the radar protection baseline for non-AAS should be applied on a ‘per antenna’ basis.²⁶⁷ We believe that this will still provide adequate protection for MOD radar systems and propose to use this definition in the new 3.6-3.8 GHz licences.²⁶⁸
- The limits above 3.8 GHz are from CEPT Report 67**
- e) CEPT Report 67 provides out-of-band emissions limits for both non-AAS and AAS above 3.8 GHz. We propose to include both limits in the 3.6-3.8 GHz licences.²⁶⁹
- Possible different limits for indoor small cells below 3390 MHz**
- f) We are currently considering whether the emissions limit below 3390 MHz can be relaxed for indoor small cells. These devices will be low power and indoors which means that they might pose a low risk of interference to radar systems below 3390 MHz.

²⁶³ Out-of-block means the spectrum which is within 3.4-3.8 GHz but outside of an individual licensee’s spectrum in the band. These emissions limits are set out in paragraphs 10 and 11 of Schedule 1 of the draft 3.6-3.8 GHz licences.

²⁶⁴ Out-of-band means spectrum which is outside of 3.4-3.8 GHz. These emissions limits are set out in paragraph 14 of Schedule 1 of the draft 3.6-3.8 GHz licences.

²⁶⁵ 44 dBm/(5 MHz) per cell TRP = (65 dBm/(5 MHz) EIRP per cell) minus (a single 21 dBi antenna).

²⁶⁶ For example, a 200 W TRP base station operating in a 40 MHz channel has a power spectral density of 44 dBm/(5 MHz) TRP per cell.

²⁶⁷ At the time the 3.4 GHz licences were awarded, EC Decision 2014/276/EU and ECC Decision 11(06) did not define whether the additional baseline to protect radar use should be applied on a “per antenna” or “per cell” basis. In the 3.4 GHz licences, we took the cautious approach of applying the limits on a “per cell” basis.

²⁶⁸ See paragraph 14 of Schedule 1 of the draft 3.6-3.8 GHz licences.

²⁶⁹ At the time the 3.4 GHz licences were awarded, EC Decision 2014/276/EU and ECC Decision 11(06) did not define out-of-band emissions limits above 3.8 GHz. For details of our proposed limits see paragraph 14 of Schedule 1 of the draft 3.6-3.8 GHz licences.

Synchronisation

11.32 Synchronisation and semi-synchronisation are mitigation techniques for reducing interference between TDD networks. In fully synchronised networks, all the base stations are either transmitting or receiving at the same time. When networks are not synchronised, some base stations will be transmitting at the same time as others are trying to receive which can result in interference and a reduction in the overall spectral efficiency of mobile networks.

11.33 Synchronisation is not necessary in FDD networks because the uplink and downlink are separated in frequency and so other mitigation techniques including duplexing filters can be used to isolate uplink signals from interfering downlink signals.

11.34 In October 2016, we confirmed our intention to award the 3.6-3.8 GHz band on a TDD basis.²⁷⁰ Therefore, synchronisation or semi-synchronisation may be necessary in this band between base stations which are not isolated from one-another.

11.35 In the 3.4 GHz licences, we require licensees to synchronise or semi-synchronise their base stations with each other,²⁷¹ which means that base stations must time align frames and operate using one of two specified frame structures:

Full synchronisation

Frame Structure A
Permissive mask

a) The fully synchronised frame structure is a 10 ms frame with a 1:3 uplink/downlink ratio²⁷² and TD-LTE frame configuration 2 using special sub-frame configuration 6 is compatible with this frame structure. A licensee operating radio equipment which uses this frame structure must comply with the Permissive emissions mask.

Semi-synchronisation

Frame Structure B
Restrictive mask

b) The semi-synchronised frame structure is a 10 ms frame which contains three synchronised sub-frames and seven flexible sub-frames which can be used for either downlink or uplink.²⁷³ This is compatible with all TD-LTE frame configurations. A licensee operating radio equipment which uses this frame structure must comply with the Restrictive mask which is required to reduce the risk of interference to adjacent mobile networks in the absence of full synchronisation.

11.36 5G NR can be made to work with the frame structures in the 3.4 GHz licences because there are 5G NR frame structures which are supported within the defined frame structures. However, it may be that the synchronisation requirements in the 3.4 GHz licences are less suitable for new 5G technologies than they were for 4G technologies. The synchronisation

²⁷⁰ "Improving consumer access to mobile services at 3.6GHz to 3.8GHz", Ofcom, 26 October 2016, https://www.ofcom.org.uk/_data/assets/pdf_file/0019/107371/Consumer-access-3.6-3.8-GHz.pdf

²⁷¹ Low power, indoor base stations are exempt from the synchronisation requirements.

²⁷² Frame Structure A has a DSUDDDSUDD structure where each character represents a 1 ms sub-frame and "D" means downlink; "U" means uplink; and "S" is a special sub-frame which contains a guard period.

²⁷³ Frame Structure B has a DSUXXXXXX structure where "X" is a flexible sub-frame which can be either uplink or downlink.

requirements that we have provisionally included in the proposed 3.6-3.8 GHz licences (see conditions 12 and 13 in the draft 3.6-3.8 GHz licences) are the same as those set out in the 3.4 GHz licences.

A higher in-block limit for terminal stations

- 11.37 CEPT Report 67 provides a mobile and nomadic terminal power limit in the 3.4-3.8GHz band of 28 dBm TRP. This limit is higher than the 25 dBm limit specified in the current 3.4-3.8 GHz EC Decision, which is reflected in the 3.4 GHz licences.
- 11.38 We are minded to include this higher power limit for terminals in the new 3.6-3.8 GHz licences. This limit is inclusive of tolerances to account for operation in extremes of temperature and manufacturing variation. Therefore, it is defined slightly differently to the in-block mobile and nomadic terminal limits specified in the 700 MHz EC Decision, which are reflected in the proposed 700 MHz licences. Once tolerances have been taken into account, 28 dBm TRP is the same as specified in 3GPP for power class 2 user equipment.²⁷⁴

Varying existing licences in 3.4–3.7 GHz to adopt the new harmonised technical conditions

- 11.39 In the longer term, licensees have said that consistent technical conditions across the whole 3.4-3.8 GHz band are likely to be attractive, for example, including the new emissions masks for AAS. This would require a variation of 3.4 GHz spectrum licence conditions and we would consider any such variation requests in accordance with our normal processes. If the 3.4 GHz licences were varied before the 3.6-3.8 GHz award then the technical licence conditions for the awarded spectrum would align with those for the varied 3.4 GHz licences.

Consultation questions

Question 13: Do you agree with the technical licence conditions we propose?

²⁷⁴ 3GPP power class 2 specifies mobile and nomadic terminal power limit of 26 dBm +2 dB to take tolerances resulting from temperature and manufacturing variation into account.

<https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3283>

A1. Responding to this consultation

How to respond

- A1.2 Ofcom would like to receive views and comments on the issues raised in this document, by 5pm on 12 March 2019.
- A1.3 You can download a response cover sheet from <https://www.ofcom.org.uk/consultations-and-statements/consultation-response-coversheet>. You can return this by email or post to the address provided below.
- A1.4 Please email to radiospectrum.award@ofcom.org.uk as an attachment in Microsoft Word format, together with the cover sheet. The email address is for this consultation only.
- A1.5 Responses may alternatively be posted to the address below, marked with the title of the consultation:
- 700 MHz and 3.6-38 GHz award,
Spectrum Group,
Ofcom,
Riverside House
2A Southwark Bridge Road
London SE1 9HA
- A1.6 We welcome responses in formats other than print, for example an audio recording or a British Sign Language video. To respond in BSL:
- Send us a recording of you signing your response. This should be no longer than 5 minutes. Suitable file formats are DVDs, wmv or QuickTime files. Or
 - Upload a video of you signing your response directly to YouTube (or another hosting site) and send us the link.
- A1.7 We will publish a transcript of any audio or video responses we receive (unless your response is confidential).
- A1.8 We do not need a paper copy of your response as well as an electronic version. We will acknowledge receipt if your response is submitted via the online web form, but not otherwise.
- A1.9 You do not have to answer all the questions in the consultation if you do not have a view; a short response on just one point is fine. We also welcome joint responses.
- A1.10 It would be helpful if your response could include direct answers to the questions asked in the consultation document. The questions are listed at annex 4. It would also help if you could explain why you hold your views, and what you think the effect of Ofcom's proposals would be.

- A1.11 If you want to discuss the issues and questions raised in this consultation, please contact John Glover on 020 7981 3000, or by email to the consultation email address radiospectrum.award@ofcom.org.uk .

Confidentiality

- A1.12 Consultations are more effective if we publish the responses before the consultation period closes. In particular, this can help people and organisations with limited resources or familiarity with the issues to respond in a more informed way. So, in the interests of transparency and good regulatory practice, and because we believe it is important that everyone who is interested in an issue can see other respondents' views, we usually publish all responses on our website, www.ofcom.org.uk, as soon as we receive them.
- A1.13 If you think your response should be kept confidential, please specify which part(s) this applies to, and explain why. Please send any confidential sections as a separate annex. If you want your name, address, other contact details or job title to remain confidential, please provide them only in the cover sheet, so that we don't have to edit your response.
- A1.14 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and try to respect it. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.
- A1.15 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's intellectual property rights are explained further at <https://www.ofcom.org.uk/about-ofcom/website/terms-of-use>.

Next steps

- A1.16 Following this consultation period, Ofcom plans to publish a statement.
- A1.17 If you wish, you can register to receive mail updates alerting you to new Ofcom publications; for more details please see <https://www.ofcom.org.uk/about-ofcom/latest/email-updates>

Ofcom's consultation processes

- A1.18 Ofcom aims to make responding to a consultation as easy as possible. For more information, please see our consultation principles in annex 2.
- A1.19 If you have any comments or suggestions on how we manage our consultations, please email us at consult@ofcom.org.uk. We particularly welcome ideas on how Ofcom could more effectively seek the views of groups or individuals, such as small businesses and residential consumers, who are less likely to give their opinions through a formal consultation.
- A1.20 If you would like to discuss these issues, or Ofcom's consultation processes more generally, please contact Jacqui Gregory, Ofcom's consultation champion:

Jacqui Gregory
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA
Email: corporationsecretary@ofcom.org.uk

A2. Ofcom's consultation principles

Ofcom has seven principles that it follows for every public written consultation:

Before the consultation

- A2.1 Wherever possible, we will hold informal talks with people and organisations before announcing a big consultation, to find out whether we are thinking along the right lines. If we do not have enough time to do this, we will hold an open meeting to explain our proposals, shortly after announcing the consultation.

During the consultation

- A2.2 We will be clear about whom we are consulting, why, on what questions and for how long.
- A2.3 We will make the consultation document as short and simple as possible, with a summary of no more than two pages. We will try to make it as easy as possible for people to give us a written response. If the consultation is complicated, we may provide a short Plain English / Cymraeg Clir guide, to help smaller organisations or individuals who would not otherwise be able to spare the time to share their views.
- A2.4 We will consult for up to ten weeks, depending on the potential impact of our proposals.
- A2.5 A person within Ofcom will be in charge of making sure we follow our own guidelines and aim to reach the largest possible number of people and organisations who may be interested in the outcome of our decisions. Ofcom's Consultation Champion is the main person to contact if you have views on the way we run our consultations.
- A2.6 If we are not able to follow any of these seven principles, we will explain why.

After the consultation

- A2.7 We think it is important that everyone who is interested in an issue can see other people's views, so we usually publish all the responses on our website as soon as we receive them. After the consultation we will make our decisions and publish a statement explaining what we are going to do, and why, showing how respondents' views helped to shape these decisions.

A3. Consultation coversheet

BASIC DETAILS

Consultation title: organisation realise

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing

Name/contact details/job title

Whole response

Organisation

Part of the response

If there is no separate annex, which parts? _____

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here.

Name

Signed (if hard copy)

A4. Consultation questions

Question 1: (Section 4) Do you agree with our proposals on the coverage obligations as set out in this section? Please give reasons supported by evidence for your views.

Question 2: (Section 5) Do you agree that we have identified the correct competition concerns?

Question 3: (Section 5) Do you agree with our assessment of these competition concerns, and our proposed measure for addressing them? Please give reasons supported by evidence for your views.

Question 4: (Section 6) Do you agree with our proposal to proceed with a conventional assignment stage?

Question 5: (Section 7) Do you agree with our proposal to use a CCA design for this award?

Question 6: (Section 7) Do you have any comments on the proposed detailed rules for our CCA design?

Question 7: (Section 8) Do you agree with our proposed approach to coexistence in the 700 MHz band?

Question 8: (Section 8) Do you have any comments on the proposed licence obligation and guidance note (annex 19)?

Question 9: (Section 9) Do you agree with our proposed approach to managing interim protections for registered 3.6-3.8 GHz band users?

Question 10: (Section 9) Do you agree with our 3.6-3.8 GHz in-band restriction zone proposals?

Question 11: (Section 9) Do you agree with our view that we do not need to include any specific conditions in 3.6-3.8 GHz licences to mitigate the risk of adjacent band interference?

Question 12: (Section 10) Do you agree with the non-technical conditions that we propose to include in the licences to be issued after the award of the 700 MHz and 3.6-3.8 GHz bands?

Question 13: (Section 11) Do you agree with the technical licence conditions we propose?